

**TRANSMITTAL LETTER TO THE UNITED STATES  
DESIGNATED/ELECTED OFFICE (DO/EO/US)  
CONCERNING A FILING UNDER 35 U.S.C. 371**

09794353-0017

U.S. APPLICATION NO. (If known, see 37 CFR 1.5)

**097889532**

INTERNATIONAL APPLICATION NO.

PCT/US00/08233

INTERNATIONAL FILING DATE

November 22, 2000

PRIORITY DATE CLAIMED

November 22, 1999

TITLE OF INVENTION DISPLAY DEVICE

APPLICANT(S) FOR DO/EO/US

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. ☐ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
  - a. ☒ is attached hereto (required only if not communicated by the International Bureau).
  - b. ☐ has been communicated by the International Bureau.
  - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
  - a. ☒ is attached hereto.
  - b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
  - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
  - b. ☐ have been communicated by the International Bureau.
  - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
  - d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371 (c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)). (Unexecuted)
10. ☐ An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

**Items 11 to 20 below concern document(s) or information included:**

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included. (Unexecuted)
13. ☒ A **FIRST** preliminary amendment.
14. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
15. ☐ A substitute specification.
16. ☐ A change of power of attorney and/or address letter.
17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
18. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. ☒ Other items or information:

Certificate of Mailing Label No: EL281568761US

U.S. APPLICATION NO. 09/8895122 (37 CFR 1.5)

INTERNATIONAL APPLICATION NO.  
PCT/US00/08233ATTORNEY'S DOCKET NUMBER  
November 22, 2000

21. <input checked="" type="checkbox"/> The following fees are submitted:				CALCULATIONS PTO USE ONLY	
<b>BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)):</b> Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO ..... \$1000.00  International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO ..... \$860.00  International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO ..... \$710.00  International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) ..... \$690.00  International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) ..... \$100.00  <b>ENTER APPROPRIATE BASIC FEE AMOUNT =</b>					
Surcharge of \$130.00 for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(e)).					
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	37 -20 =	17	x \$18.00	\$ 306.00	
Independent claims	37 -3 =	34	x \$80.00	\$ 2,720.00	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ \$270.00	\$	
<b>TOTAL OF ABOVE CALCULATIONS =</b>				\$ 3,886.00	
<input type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.				\$	
<b>SUBTOTAL =</b>				\$	
Processing fee of \$130.00 for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				\$	
<b>TOTAL NATIONAL FEE =</b>				\$ 3,886.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property +				\$ 0.00	
<b>TOTAL FEES ENCLOSED =</b>				\$ 3,886.00	
				Amount to be refunded:	\$
				charged:	\$

- a. ☒ A check in the amount of \$ 3,886.00 to cover the above fees is enclosed.
- b. ☐ Please charge my Deposit Account No. \_\_\_\_\_ in the amount of \$ \_\_\_\_\_ to cover the above fees.  
A duplicate copy of this sheet is enclosed.
- c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any  
overpayment to Deposit Account No. 19-3140. A duplicate copy of this sheet is enclosed.
- d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card  
information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

**NOTE:** Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137 (a) or (b)) must be filed and granted to restore the application to pending status.

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32,919  
REGISTRATION NUMBER

IN THE UNITED STATES ELECTED OFFICE  
OF THE UNITED STATES PATENT AND TRADEMARK OFFICE  
UNDER THE PATENT COOPERATION TREATY-CHAPTER II

PRELIMINARY AMENDMENT

APPLICANT(S): Jiro Yamada, et al. ) ATTORNEYS DOCKET NO:  
SERIAL NO: ) 09794353-0017  
Filed: )  
INTERNATIONAL )  
APPLICATION NO: PCT/JP00/08233 )  
INTERNATIONAL )  
FILING DATE: 22 November 2000 )  
TITLE: DISPLAY DEVICE )

Hon. Assistant Commissioner for Patents  
Washington, D.C. 20231

SIR:

Please amend the above-identified International Application before entry into the national stage at the U.S. Patent and Trademark Office as follows.

IN THE SPECIFICATION:

Please amend the specification as follows:

On page 1, line 1 delete "DESCRIPTION" and insert

--TITLE--

On page 1, line 4 add

--BACKGROUND OF THE INVENTION --

On page 1, line 5 delete "Technical Field" and insert

--FIELD OF THE INVENTION--

At page 5, line 14 delete "Disclosure of Invention" and insert

--SUMMARY OF THE INVENTION--

At page 14, line 20, delete "Best Mode For Carrying Out the Invention" and insert

**--DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS--**

At page 40, line 1, after "Claims" insert

**--WHAT IS CLAIMED IS--**

### R E M A R K S

The foregoing Preliminary Amendment is made to place the specification into U.S. format. No new matter has been added. Applicants look forward to early and favorable action by the Examiner.

Respectfully submitted,



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11180390

18/PR75

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## DESCRIPTION

### DISPLAY DEVICE

#### 5      Technical Field

This invention relates to a display device and, more particularly, to a spontaneous emission-type display device such as organic electroluminescence device.

#### 10     Background Art

A device using electroluminescence of an organic material (hereinafter called "organic EL device") is made of an organic layer in which an organic hole transport layer, or organic light emitting layer, interposed between a first electrode and a second electrode, and it is remarked as a spontaneous emission type display device capable of high-luminance emission by low-voltage d.c. driving.

Fig. 1 shows a cross-sectional configuration of a central part of a transmission-type organic EL device as one of such organic EL devices. The organic EL device shown in Fig. 1 is made by stacking on a transparent substrate 1, sequentially from bottom to top, a transparent electrode 2, organic buffer layer 3, organic hole transport layer 4, organic light emitting layer 5 and metal electrode 6, and light h generated in the organic light emitting layer 5 is extracted through

the substrate 1.

In the organic EL device shown in Fig. 1, however, spectrums of respective colors in the light h generated in and extracted from the organic light emitting layer 5 having various emission colors have wide peak widths as shown in Fig. 2, and especially regarding the red light h, the peak wavelength is deviated to a lower wavelength. Therefore, with a display apparatus made by using such organic EL devices for color representation, it was impossible to obtain a sufficient color reproduction range enough to display, for example, TV images.

To overcome this problem, it was proposed to interpose a dielectric mirror layer (not shown) between the substrate 1 and the transparent electrode 2 such that the dielectric mirror layer, organic buffer layer e, organic hole transport layer 4, organic light emitting layer 5 and metal electrode 6 form a cavity structure. In the organic EL device having this cavity structure, light h generated in the organic light emitting layer 5 reciprocally moves between the dielectric mirror layer and the metal electrode 6, and only a part of light with the resonant wavelength is extracted through the substrate 1. Therefore, light h having a high peak intensity and a narrow spectrum can be extracted, and it is possible to enlarge the color reproduction range of a display apparatus using such

organic EL devices.

However, as the peak width of the spectrum of extracted light h is narrowed, as it is in the organic EL device having the above-mentioned cavity structure, dependency of the emission property on the view angle increases. For example, when the emission surface is viewed from an aslant direction, wavelength of light h largely shifts and the emission intensity decreases. Therefore, it is important that the spectral width of light extracted from the organic EL device is not narrow too much. However, the organic EL device does not envisage the dependency of the view angle in its design, and could not maintain a sufficient color reproduction range over wide view angles.

Moreover, the organic EL device, in problem, had to optimize the cavity structure for light h of each color to be extracted, and required an additional effort for it.

Further, in the organic EL device shown in Fig. 1, because external light intruding from outside the device is reflected by the metal electrode 6, its external light reflectance is high and this results in a low contrast under external light. As a technique for preventing it, Japanese Patent Laid-Open Publication No. hei 9-127885 discloses an organic EL display apparatus having a combination of a  $1/4$  wavelength panel and a linear polarizing panel disposed

in front of the front surface, as shown in Fig. 3.

More specifically, this organic EL display apparatus  
locates a combination of a  $1/4$  wavelength panel 8 and a  
linear polarizing panel 9 in front of a substrate 1 in  
an organic EL device having the same configuration  
already explained with reference to Fig. 1 for the  
purpose of preventing reflection of external light. It  
is also proposed to replace the metal electrode  
behaving as a reflective surface with a transparent  
electrode and providing a light absorbing layer on side  
of the transparent electrode opposite from the organic  
layer such that the light absorbing layer absorbs  
external light and prevents reflection of external  
light. However, in those display apparatuses having  
those configurations, extraction and reflection of  
light generated in the display apparatus are also  
prevented, and their luminance decreases to about 50%.

It is also proposed to dispose color filters  
transmitting red (R), green (G) and blue (B) colors,  
respectively, on respective color emission pixels.  
Although display devices with this configuration could  
prevent reflection of external light other than emitted  
light, they cannot prevent reflection of external light  
outside the wavelength ranges of the emission colors of  
respective pixels.

It is therefore an object of the invention to  
provide a spontaneous emission type display device that



can maintain a sufficient color reproduction range over a wide view angle.

Another object of the invention is to provide a spontaneous emission type display device that can reduce reflection of external light and thereby improves the contrast without inviting a decrease in luminance.

A further object of the invention is to provide a spontaneous emission type display device that can maintain a sufficient color reproduction range over a wide view angle and can improve the contrast by reducing reflection of external light without inviting a decrease in luminance.

#### Disclosure of Invention

To accomplish the above objects, according to the invention, there are provided display devices each including a light emitting layer interposed between a first electrode of a light reflective material and a second electrode of a transparent material such that at least one of the second electrode and the light emitting layer serves as a cavity portion of a cavity structure, in which the cavity portion has any of the configurations shown below.

In the first display device, when the phase shift produced in light generated in the light emitting layer when reflected by opposite ends of the cavity portion is  $\Phi$  radians,  $L$  is optical path length of the

cavity portion, and  $\lambda$  is the peak wavelength of the spectrum of part of light to be extracted, optical path length  $L$  of the cavity portion takes a positive minimum value in a range satisfying the equation:

5 
$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (m is an integer)} \quad (1)$$

In the first display device having the above-summarized configuration, since the optical path length  $L$  of the cavity portion satisfies Equation (1), multiple interference of light near the wavelength  $\lambda$  occurs in the cavity portion. Additionally, since the optical path length  $L$  of the cavity portion is controlled to be the positive minimum value in the range satisfying Equation (1), spectrum of the extracted light is maintained in the widest width in the range inducing multiple interference of the light with the wavelength  $\lambda$ . As a result, in the display device, while the spectrum of the extracted light keeps a certain width, the peak intensity is enhanced by multiple interference. Therefore, the display device exhibits only a small shifting amount of the wavelength  $\lambda$  even when viewed from different view angles and provides an improved color purity in a wider view angle range.

In the second display device, when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians,  $L'$  is optical path length

of said cavity portion, and  $\lambda$  is the peak wavelength of the spectrum of green light, optical path length  $L'$  of said cavity portion is determined to satisfy the following equation (3) which is made by adding 4 to the integer  $m_1$  that is one of integers  $m$  satisfying the following equation (2), with which  $L$  takes a positive minimum value.

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (m is an integer)} \quad (2)$$

$$(2L')/\lambda + \Phi/(2\pi) = m_1 + 4 \quad (3)$$

In the second display device having the above-summarized configuration, multiple interference occurs in light with wavelengths corresponding to red (R), green (G) and blue (B) in the cavity portion. As a result, peak intensity of spectrum of each emitted light can be enhanced without setting optical path length  $L'$  of the cavity portion specifically for each color. Therefore, a common optical path length  $L'$  of the cavity portion can be used in all display devices corresponding to respective emitted colors.

In the third display device, when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians,  $L'$  is optical path length of said cavity portion, and  $\lambda$  is the peak wavelength of the spectrum of green light, optical path length  $L'$  of said cavity portion is determined to satisfy the following equation (5) which is made by adding an

integer not smaller than 10 to the integer  $m_1$  that is one of integers  $m$  satisfying the following equation (4), with which  $L$  takes a positive minimum value.

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (} m \text{ is an integer)} \quad (4)$$

$$(2L')/\lambda + \Phi/(2\pi) = m_1 + q \quad (5)$$

In this display device, multiple interference occurs among a number of light components with different wavelengths in each of the ranges of red (R), green (G) and blue (B) in the cavity portion. As a result, in a color display apparatus using such display devices, a common optical path length  $L'$  of the cavity portion can be used in all display devices corresponding to respective emitted colors. Moreover, since light of each emission color extracted after multiple interference is composed of a plurality of peaks, entire spectral width of extracted light  $h$  is virtually wider. Therefore, in this display device, shifting of the wavelength  $\lambda$  is limited to a small value even when viewed from different view angles and the color purity is improved in a wider view angle range.

The fourth display device according to the invention is characterized in that a color filter for transmitting light which resonates in said cavity portion and is to be extracted through said second electrode is provided above said second electrode.

In the display device having the above-

summarized configuration, if the wavelength of the light extracted from the second electrode after resonance in the cavity portion is the target wavelength, only a part of external light having the target wavelength, which is contained in the external light irradiated from the second electrode side, can transmit the color filter and reaches the cavity portion. Since the cavity portion used here is a cavity filter for the target wavelength, its transmittance for the target wavelength range is very high. That is, reflectance to light in the target wavelength range is very low. Therefore, this cavity portion prevents reflection of external light passing through the color filter and belonging to the same wavelength range as the target wavelength. On the other hand, external light outside the target wavelength range is prevented from intruding into the device by the color filter and from reflection by the color filter. As a result, reflection of external light containing light within the target wavelength range is prevented without disturbing extraction of the emitted light in the target wavelength range from the second electrode side.

The fifth to seventh display devices are combinations of the first to third display devices with the fourth display device, respectively.

According to further inventions for

accomplishing the above objects, there are provided display devices each having a light emitting layer between a first electrode and a second electrode such that at least one of the light emitting layer and one of the first electrode and the second electrode, from which light is extracted, serves as a cavity portion of a cavity structure, and characterized in that the cavity portions have the same configurations as those of the first to seventh display devices.

According to still further inventions for accomplishing the above objects, there are provided display devices each having a first electrode of a light reflective material, light emitting layer and a second electrode of a transparent material which are sequentially stacked on a substrate such that at least one of the second electrode and the light emitting layer serves as a cavity portion of a cavity structure, and characterized in that the cavity portions have the same configurations as those of the first to seventh display devices.

According to yet further inventions for accomplishing the above objects, there are provided display devices each having a first electrode of a light reflective material, light emitting layer and a second electrode of a transparent material which are sequentially stacked on a substrate such that at least one of the second electrode and the light emitting

layer serves as a cavity portion of a cavity structure,  
and characterized in that the cavity portions have the  
same configurations as those of the first to seventh  
display devices. Typically, in each of those display  
5 devices, the light emitting layer serves as the cavity  
portion of the cavity structure, or the second  
electrode serves as the cavity portion of the cavity  
structure.

According to a yet further invention for  
10 accomplishing the above objects, there is provided a  
display device having a light emitting layer interposed  
between a first electrode of a light reflective  
material and a second electrode of a transparent  
material and so configured that at least one of said  
15 second electrode and said light emitting layer serves  
as a cavity portion of a cavity structure,  
characterized in that, when optical path length of said  
cavity portion is  $L$ , said optical path length  $L$  is  
determined so determined that difference between the  
20 peak wavelength of the spectrum of light to be  
extracted upon a change in view angle and the peak  
wavelength of the internal emission spectrum (for  
example, spectrum of light generated in the organic  
light emitting layer 13c in embodiments described later  
25 and extracted directly not through multiple  
interference) is limited within one half of the half-  
width (FWHM) of said internal emission spectrum.

## Brief Description of Drawings

Fig. 1 is a cross-sectional view that shows a configuration of a central part of a conventional organic EL device; Fig. 2 is a schematic diagram that shows color spectrums extracted from a conventional organic EL device; Fig. 3 is a schematic diagram that shows a configuration of a conventional display device directed to preventing reflection of external light; Fig. 4 is a cross-sectional view that shows a central part of an organic EL device according to the first embodiment of the invention; Fig. 5 is a schematic diagram that shows a simulation of light spectrums extracted from the organic EL device according to the first embodiment of the invention; Fig. 6 is a schematic diagram that shows a simulation of spectrums to show the filtering property of the organic layer itself in the organic EL device according to the first embodiment of the invention; Fig. 7 is a schematic diagram that shows a simulation of internal emission spectrums in the organic EL device according to the first embodiment of the invention; Fig. 8 is a schematic diagram that shows a simulation of light spectrums extracted from a conventional EL device; Fig. 9 is a schematic diagram that shows a simulation of spectrums to show the filtering property of the organic layer itself in the conventional organic EL device;



Fig. 10 is a schematic diagram that shows dependency of the organic EL device (G emission) according to the first embodiment of the invention upon the view angle; Fig. 11 is a schematic diagram that shows dependency of the conventional organic EL device (G emission) upon the view angle; Fig. 12 is a schematic diagram that shows chromaticity coordinates of the organic EL device according to the first embodiment of the invention and a comparative example; Fig. 13 is a cross-sectional view that shows a central part of an organic EL device according to the second embodiment of the invention; Fig. 14 is a schematic diagram that shows a simulation of spectrums to show the filtering property of the organic layer itself in the organic EL device according to the second embodiment of the invention; Fig. 15 is a cross-sectional view that shows a central part of an organic EL device according to the third embodiment of the invention; Fig. 16 is a schematic diagram that shows a simulation of spectrums to show the filtering property of the organic layer itself in the organic EL device according to the third embodiment of the invention; Fig. 17 is a schematic diagram that shows a simulation of light spectrums extracted from the organic EL device (G emission) according to the third embodiment of the invention; Fig. 18 is a cross-sectional view that shows a central part of a further organic EL device to which the invention is applied;

Fig. 19 is a cross-sectional view that shows a central part of an organic EL device according to the fourth embodiment of the invention; Fig. 20 is a schematic diagram that shows a simulation of spectrums to show the external light reflection property of the organic EL device according to the fourth embodiment of the invention, when using no color filter; Fig. 21 is a schematic diagram that shows spectrums representing transmission properties of different color filters used in the organic EL device according to the fourth embodiment of the invention; Fig. 22 is a schematic diagram that shows a simulation of spectrums to show the external light reflection property of the organic EL device according to the fourth embodiment of the invention; and Fig. 23 is a cross-sectional view that shows an alternative configuration of the central part of the organic EL device according to the fourth embodiment.

#### Best Mode for Carrying Out the Invention

Explained below are some embodiments of the invention with reference to the drawings. Here are explained embodiments of display device as applying the invention to organic EL devices.

Fig. 4 shows an organic EL device according to the first embodiment of the invention. The organic EL device shown in Fig. 4 is a so-called top surface

emission type organic EL device, and includes a first electrode 12, organic layer 13, semitransparent reflection layer 14 and second electrode 15 stacked on a substrate 11 sequentially from bottom to top.

5           The substrate 11 is, for example, a transparent glass substrate, semiconductor substrate, or the like, and may be flexible.

10           The first electrode 12 is used as an anode electrode that functions as a reflection layer as well, and it is made of a light reflective material such as platinum (Pt), gold (Au), chromium (Cr), tungsten (W), or the like. The first electrode 12 preferably has a thickness in the range from 100 nm to 300 nm.

15           The organic layer 13 is made by stacking, for example, a buffer layer 13a, hole transport layer 13b and organic light emitting layer 13c also functioning as an electron transport layer, sequentially from bottom. The electron transport layer may be provided separately from the organic light emitting layer 13c.

20           The buffer layer 13a is a layer for preventing leakage, and may be made of, for example, m-MTDATA [4, 4', 4"-tris (3-methylphenylphenylamino) triphenylamine], 2-TNATA [4, 4', 4"-tris (2-naphthylphenylamino) triphenylamine], or the like. The buffer layer 13a may

25           be omitted if leakage is in an acceptable level. The hole transport layer 13b may be made of, for example,  $\alpha$ -NPD [N, N'-di (1-naphthyl)-N, n'-diphenyl-[1, 1'-

biphenyl]-4, 4'-diamine]. The organic light emitting layer 13c is made of different light emitting materials having emission colors of red (R), green (G) and blue (B). For example, as the light emitting material having the G emission color, Alq3 (tris-quinolinolaluminum complex) may be used.

These layers forming the organic layer 13 are preferably in specific thickness ranges, i.e. for the buffer layer 13a from 15 nm to 300 nm, for the hole transport layer 13b from 15 nm to 100 nm and for the organic light emitting layer 13c from 15 nm to 100 nm, respectively. However, thicknesses of the organic layer 13 and the layers forming it are determined so that their optical film thicknesses become the values explained later.

The semitransparent reflection layer 14 form a cathode electrode, and it is made of, for example, magnesium (Mg), silver (Ag) or their alloy. The semitransparent reflection layer 14 preferably has a thickness in the range from 5 nm to 50 nm.

The second electrode 15 is made of a material typically used as a transparent electrode, such as indium tin oxide (ITO) or an oxide of indium and zinc. Let the second electrode 15 have a thickness in the range from 30 nm to 1000 nm. A passivation film (not shown) made of a transparent dielectric overlies the second electrode 15. The transparent dielectric

preferably has a refractive index approximately equal to that of the material forming the second electrode 15. As such material, silicon oxide ( $\text{SiO}_2$ ), silicon nitride ( $\text{SiN}$ ), or the like, can be used, and may be stacked to a thickness from 500 nm to 10000 nm, for example.

In this EL device, the first electrode 12 of a light reflective material, organic layer 13 and semitransparent reflection layer 14 make up a cavity structure, and the organic layer 13 functions as a cavity portion. Therefore, optical path length  $L$  between the first electrode 12 and the semitransparent reflection layer 14, i.e. the optical thickness of the cavity portion, which is the organic layer 13, is determined to satisfy the following equation (6), and in this range, optical path length  $L_{\min}$  that is the positive minimum value is especially employed.

$$(2L)/\lambda + \Phi / (2\pi) = m \quad (m \text{ is an integer}) \quad (6)$$

where the phase shift produced when the light  $h$  generated in the organic light emitting layer 13c reflects at the first electrode 12 and the semitransparent reflection layer 14 is  $\Phi$  radian, and  $\lambda$  is the peak wavelength of the spectrum of the light  $h$  to be extracted from the light  $h$  emitted in the organic light emitting layer 13c.

Thicknesses of respective layers forming the organic layer 13 are determined to satisfy it. Optical

distance L of the cavity portion is determined by the following equation (7) from refractive indices  $n_1, n_2, \dots, n_k$  and thicknesses  $d_1, d_2, \dots, d_k$  of respective layers of the organic layer 13 (buffer layer 13a, hole transport layer 13b and organic light emitting layer 13c in the first embodiment).

$$L = n_1 \times d_1 + n_2 \times d_2 + \dots + n_k \times d_k \quad (7)$$

An example of calculation of L is shown here.

If the buffer layer 13a is made of 2-TNATA, the hole transport layer 13b is made of  $\alpha$ -NPD, the organic light emitting layer 13c is made of Alq3, their thicknesses are  $d_1=32\text{nm}$ ,  $d_2=30\text{nm}$ ,  $d_3=50\text{nm}$ , respectively, and  $\lambda=535\text{nm}$ , then  $n_1=1.9$ ,  $n_2=1.8$  and  $n_3=1.7$ . Therefore,

$$L = 1.9 \times 32 + 1.8 \times 30 + 1.7 \times 50 = 200 \text{ nm}$$

$\Phi$  is derived as follows. That is, first stacked on a substrate (for example, Si substrate) is the reflection layer (Cr, or the like) or a semitransparent reflection layer (Mg, Ag, Mg-Ag alloy, or the like) to a thickness not thinner than 200 nm. Then using a spectroellipsometric apparatus (for example, a product of the manufacturer SOPRA), refractive index  $n$  and absorption coefficient  $k$  of the reflection layer or semitransparent reflection layer is determined.

The phase shift of the reflection layer can be calculated from its  $n$  and  $k$ , and refractive index  $n$  of the organic layer in contact with the reflection

layer (see, for example, Principles of Optics, Max Born and Emil Wolf, 1974 (PERGAMON PRESS)).

The phase shift of the semitransparent reflection layer can be similarly calculated by using its  $n$  and  $k$ , as well as refractive index  $n$  of the organic layer in contact with the semitransparent reflection layer, thickness of the semitransparent reflection layer, refractive indices and thicknesses of respective transparent films over it. Also the refractive indices of the organic layer and respective transparent films can be measured using a spectroellipsometric apparatus.

The sum of those two phase shift amounts is  $\Phi$ .

As an exemplary value of  $\Phi$ ,  $\Phi = -4.7$  radians when  $\lambda = 535$  nm.

In the organic EL device having the above-explained configuration, the first electrode 12 as the reflection layer, organic layer 13 and semitransparent reflection layer 14 make up a cavity structure, the organic layer 13 as the cavity portion functions as a narrow-band-pass filter, and only the light  $h$  near the peak wavelength  $\lambda$  of the spectrum to be extracted is enhanced by multiple interference and extracted through the second electrode 15. Therefore, light  $h$  of a spectrum having a high peak intensity is extracted. In addition, since thickness of the organic layer 13 is

adjusted to the positive minimum value within values acceptable for the first electrode 12, organic layer 13 and semitransparent reflection layer 14 to make up a cavity structure, spectrum of the extracted light  $h$  is kept widest within the range bringing about multiple interference of light having the wavelength  $\lambda$ .

Fig. 5 shows a simulation of light spectrums extracted from organic EL devices different in emission color, designed as explained above (as applied here,  $m=0$  in Equation (6)). Chromium was used as the first electrode 12, and silver-magnesium alloy was used as the semitransparent reflection layer 14. Fig. 6 shows a simulation of spectrums to show the property as a simple filter of each organic layer 13 having the same design. The spectrums shown in Fig. 5 are obtained by multiplying respective spectrums of Fig. 5 by spectrums of light extracted without multiple interference after being emitted in the organic light emitting layer 13c, that is, internal emission spectrums shown in Fig. 7.

As a comparative example, Fig. 8 shows a simulation of spectrums of light extracted from EL devices in which optical path length  $L$  satisfying Equation (6) does not become the positive minimum value (here  $m=1$ ). Organic EL devices taken as the comparative example have the same configuration as the first organic EL device except for the optical path length  $L$  of the cavity portion. Thickness of each



organic layer 13 was adjusted by adjusting the thickness of the buffer layer 13a to be 240 nm in the organic EL device for emission of light in the red (R) region, 190 nm in the organic EL device for emission of light in the green (G) region, and 150 nm in the organic EL device for emission of light in the blue (B) region. Fig. 9 shows a simulation of spectrums to show the property as a simple filter of each organic layer having the same design as the comparative example. Spectrums shown in Fig. 8 are obtained by multiplying spectrums shown in Fig. 9 by spectrums of light extracted without multiple interference after being emitted in the organic light emitting layer 13c, that is, internal emission spectrums shown in Fig. 7.

As apparent from comparison of these figures, by determining the thickness of the organic layer 13 like the first embodiment, while subjecting the light h extracted from the organic EL device to multiple interference, its spectrum can maintain a certain width. Therefore, in the organic EL device according to the first embodiment, even when the view angle is offset, the shift amount of the wavelength  $\lambda$  can be limited to a small value, and color purity can be improved over a wider view angle range.

Fig. 10 shows dependency of the organic EL device ( $m=0$ ) according to the first embodiment of the invention upon the view angle. Here is shown a light

spectrum of the green (G) wavelength measured from angles of 0° (straight forward), 30° and 60° relative to the display plane. Fig. 11 is a graph that shows dependency of an organic EL device (m=1) as a comparative example upon the view angle.

As apparent through comparison of Figs. 10 and 11, in the organic EL device according to the first embodiment, the spectral peak does not shift substantially even when the view angle is offset by 30°, and even when the view angle is offset 60°, shifting of the spectral peak is within about 10 nm. In contrast, in the organic EL device taken as the comparative example, when the view angle is offset by 60°, the spectral peak shifts toward shorter wavelengths as much as 30 nm as shown in Fig. 11, and the color has changed. It has been confirmed from the comparison that the organic EL device according to the first embodiment can restrict shifting of the peak position of the spectrum of the extracted light h within a smaller value than the organic EL device as the comparative example even when the view angle is large.

Its reason is shown below. That is, when viewed obliquely from  $\theta$  radians, Equation (6) can be rewritten as the following equation (8).

$$(2L)/\lambda' \times \cos \theta + \Phi/2(\pi) = m \quad (m \text{ is an integer}) \quad (8)$$

If  $\lambda' = \lambda + \Delta\lambda$  ( $\lambda$  is the peak wavelength of the

filter property spectrum when the light emitting surface is viewed from the frontal direction), then  $\Delta\lambda=(1-\cos\theta)\lambda$ , the shift amount  $\Delta\lambda$  of the peak of the filter property spectrum does not depend on the integer m defining the thickness of the organic layer for making up the cavity structure, but merely depends upon the view angle.

However, for a reason explained later, with a smaller m, the filter property spectrum is gentler and wider, i.e. broader, and the shifting amount of the peak of the spectrum of the extracted light is smaller. Therefore, in the organic EL device according to the first embodiment, color purity is improved in a wider view angle range. As a result, in a direct view type color display apparatus made by using this organic EL device, a sufficient color reproduction range can be ensured over wider view angles.

The phenomenon that the filter property spectrum becomes broader with a small m as explained above occurs by the following reason. In case the sum of the phase shifting values of reflected light generated in the anode electrode, i.e. first electrode 12, and the cathode electrode, i.e. semitransparent reflection layer 14 is  $\Phi$  radians, L is the optical path length of the organic layer 13, and  $\lambda$  is the wavelength of light, if the phase delay per each multiple interference is  $\delta$ ,

$$\delta = 2\pi \cdot 2L/\lambda + \Phi \quad (9)$$

Here, a value of  $\lambda$  satisfying

$$\delta = 2\pi \cdot m \text{ (m is an integer)} \quad (10)$$

is the peak wavelength of the narrow-band-pass filter.

When it is  $\lambda_{\max}$ , then from Equations (9) and (10),

$$2L/\lambda_{\max} + \Phi/2\pi = m \text{ (m is an integer)} \quad (11)$$

is obtained. As the optical path length  $L$  becomes smaller in Equation (9), the spectral width of the narrow-band-pass filter becomes broader with a smaller  $m$  as will be understood from the fact that the changing amount of  $\delta$  relative to the changing amount of  $\lambda$  decreases.

Fig. 12 is a schematic diagram that shows chromaticity coordinates of light extracted from the organic EL device according to the first embodiment (the present invention), made by actual measurement using a chromatic photometer (BM-7 by Topcon Corporation). Also shown as a comparative example are chromaticity coordinates (conventional) corresponding to the spectrum of light extracted from the conventional organic EL device already explained by using chromaticity coordinates (CRT) of CRT (cathode ray tube) and Fig. 1. In Fig. 12, the curve portion of the outermost line shows the spectrum locus, and the linear portions thereof show the purple boundary. As understood from comparison of these chromaticity coordinates, it has been confirmed that chromaticity

coordinates of the organic EL device according to the first embodiment represent a significantly enlarged color reproduction range as compared with the conventional one and that substantially the same color reproduction range as CRT is ensured.

Fig. 13 shows an organic EL device according to the second embodiment of the invention. The organic EL device shown in Fig. 13 is based on the organic EL device according to the first embodiment shown in Fig. 4, but its cavity structure is made up of the semitransparent reflection layer 14, second electrode 15 and the top end interface (for example, interface with the atmospheric layer) of the second electrode. Reflectance at the interface between the end surface of the second electrode 15 and the atmospheric layer is as large as approximately 10%, and here are used effects of the cavity having the second electrode 15 made of a transparent material as its cavity portion.

Therefore, as the distance between the atmospheric layer and the semitransparent reflection layer 14, i.e. optical path length  $L$  (here is expressed as  $L_2$  for the purpose of distinction from the first embodiment) of the cavity portion the second electrode 15 forms, here is employed the optical path length  $L_2$  that satisfies the following equation (13) made by adding 4 to the value of  $m$  ensuring  $L_1$  to become the positive minimum value (such  $m$  is written as  $m_1$ ) among

values of  $m$  satisfying the following equation (12).

Assume here that the phase shift produced when light  $h$  generated in the organic light emitting layer 13c reflects at the opposite ends of the cavity portion (second electrode 15) is  $\Phi$ , and the peak wavelength of the spectrum of the light is  $\lambda$ . In case a passivation film of a transparent dielectric material having a refractive index equivalent to the second electrode 15 is provided on the second electrode 15, the passivation film and the second electrode 15 function as the cavity portion.

$$(2L_1)/\lambda + \Phi/(2\pi) = m \quad (m \text{ is an integer}) \quad (12)$$

$$(2L_2)/\lambda + \Phi/(2\pi) = m1 + 4 \quad (13)$$

The cavity portion (i.e. second electrode 15) thus designed brings about multiple interference of light of respective wavelengths corresponding to the red (R), green (G) and blue (B) regions as shown in Fig. 14. Therefore, optical path length  $L_2$  of the cavity portion need not be determined for each color, and a common optical path length  $L_2$  can be used in cavity portions in form of second electrodes 15 in all organic EL devices corresponding to respective emission colors.

Fig. 15 shows an organic EL device according to the third embodiment of the invention. The organic EL device shown in Fig. 15 is based on the organic EL device according to the first embodiment shown in Fig.

14, but its cavity structure is made up of the semitransparent reflection layer 14, second electrode 15 and the top end interface (for example, atmospheric layer) of the second electrode 15.

5                   As the distance between the atmospheric layer and the semitransparent reflection layer 14 in this organic EL device, i.e. optical path length L (here is expressed as  $L_3$  for the purpose of distinction from the first embodiment and the second embodiment) of the  
10 cavity portion the second electrode 15 forms, here is employed the optical path length  $L_3$  that satisfies the following equation (15) made by adding an integer  $q$  not smaller than 10, preferably an integer  $q_1$  not smaller than 18, to the value of  $m$  ensuring  $L_1$  to become the  
15 positive minimum value (such  $m$  is written as  $m_1$ ) among values of  $m$  satisfying the following equation (14). Assume here that the phase shift produced when light  $h$  generated in the organic light emitting layer 13c reflects at the opposite ends of the cavity portion  
20 (second electrode 15) is  $\Phi$ , and the peak wavelength of the spectrum of the light is  $\lambda$ . In case a passivation film of a transparent dielectric material having a refractive index equivalent to the second electrode 15 is provided on the second electrode 15, the passivation  
25 film and the second electrode 15 function as the cavity portion.

$$(2L_1)/\lambda + \Phi/(2\pi) = m \text{ (} m \text{ is an integer) } \quad (14)$$

$$(2L_3)/\lambda + \Phi/(2\pi) = m1 + q \quad (15)$$

The cavity portion (i.e. second electrode 15) thus designed brings about multiple interference of light of a large number of wavelengths corresponding to the red (R), green (G) and blue (B) regions as shown in Fig. 14. Therefore, similarly to the second embodiment, optical path length  $L_3$  of the cavity portion need not be determined for each color, and a common optical path length  $L_3$  can be used in cavity portions in all organic EL devices corresponding to respective emission colors. In addition to that, as shown in Fig. 17, since the light extracted after multiple interference (light in the green (G) region in Fig. 17) results in having a plurality of fine peaks, the entire spectral width of the extracted light  $h$  becomes substantially wider. Therefore, similarly to the organic EL device according to the first embodiment, color purity can be improved over wider view angles. As a result, a direct-view color display apparatus made by using the organic EL device exhibits a sufficient color reproducibility in wide view angles.

The second and third embodiments are applicable either in combination with the first embodiment or independently. Configurations of the cavity portions explained as the second and third embodiments are also applicable to the cavity portion made up of the organic layer 13. However, cavity



portions explained in the second and third embodiments will be optimum for use in a configuration using as the cavity portion the second electrode 15 having a relatively high freedom toward a thicker thickness.

5 Additionally, structure of the cavity portion explained in the first embodiment is applicable also to cavity portion made up of the second electrode 15 (and the passivation film thereon).

10 Further, the foregoing embodiments are not limited to application to the top surface emission type organic EL device as shown in Fig. 4. For example, although the anode electrode explained as being the first electrode 12 made of a metal film having a high work function, it may be made in form of a two-layered structure stacking a transparent electrically  
15 conductive film on a dielectric multi-layered film or a reflection film of aluminum (Al), for example. In this case, this reflection film serves as the first electrode in the context of the invention. The  
20 transparent conductive film forms a part of the cavity portion.

25 Furthermore, the embodiments are applicable also to the structure as shown in Fig. 18, in which the first electrode 12 is a cathode electrode made of a light reflective material, the second electrode 15 is an anode electrode made of a transparent electrode, and the organic light emitting layer 13c, hole transport

layer 13b and buffer layer 13c are stacked sequentially from the first electrode 12. In this case, the organic layer 13 and the second electrode 15 in combination are used as one cavity portion, and light generated in the organic light emitting layer 13c is reflected by the bottom end of the organic layer 13 (interface with the first electrode 12) and the top end of the second electrode 14 (interface with the atmospheric layer). Additionally, in this configuration, a semitransparent reflection layer (not shown) made of a material having a high work function, such as Pt, Au or Cr, can be used also in a configuration interposing it between the organic layer 13 and the second electrode 15. In this case, structure of the cavity portion will be the same as those of the first to third embodiments.

The invention is not limited to top surface emission type organic EL devices, but it is also applicable to transmission type organic EL devices using a transparent substrate 11, although not explained with reference to drawings. Further, it is also applicable to organic EL devices connected to a thin film transistor on the substrate 11.

(Fourth Embodiment)

Fig. 19 is a cross-sectional view that shows a central part of an organic EL device according to the fourth embodiment of the invention. The organic EL device shown in Fig. 19 includes a color filter in

addition to the top surface emission type organic EL device according to the first embodiment shown in Fig. 4. More specifically, the first electrode 12 as the reflection layer, organic layer 13 and semitransparent reflection layer 14 make up the cavity structure, with the organic layer 13 as the cavity portion, and a color filter 20 is disposed on the semitransparent reflection layer 14 via the second electrode (transparent electrode) 15 and the passivation film 16.

Let the color filter 20 be configured to transmit only light  $h$  near the peak wavelength  $\lambda$  of a spectrum to be extracted from the organic EL device. That is, a device for emitting light in the red (R) region has a color filter 20R that transmits light exclusively in the red (R) region, a device for emitting light in the green (G) region has a color filter 20G that transmits light exclusively in the green (G) region, and a device for emitting light in the blue (B) region has a color filter 20B that emits light exclusively in the blue (B) region.

Optical distance  $L$  of the cavity portion, which is the organic layer 13, is designed to be widest in the range bringing about multiple interference of light  $h$  near the peak wavelength  $\lambda$  of the spectrum to be extracted as already explained in the first embodiment. The wavelength range of the light  $h$  to be extracted from each organic layer 13 preferably

coincides with the wavelength range in which each color filter 20 exhibits the highest transmittance.

In the organic EL device with this configuration, among external light H irradiated from the display surface side (surface nearer to the color filter 20), only light  $H_1$  near the peak wavelength  $\lambda$  of the spectrum to be extracted from the organic EL device can transmit the color filter 20 and reaches the cavity portion (organic layer 13 in this case), and external light with other wavelengths is prevented from intruding inside the device beyond the color filter 20.

Since the cavity portion (i.e. organic layer 13) is a narrow-band-pass filter that transmits light near the peak wavelength  $\lambda$  to be extracted, its transmittance for the external light  $H_1$  near the peak wavelength  $\lambda$  is very high. That is, reflectance to the external light  $H_1$  is very low. Therefore, external light  $H_1$  near the peak wavelength  $\lambda$  intruding through the color filter 20 is prevented from reflection in the organic layer 13 and from again passing through the color filter 20 to radiate externally.

Fig. 20 shows a result of simulation of external light reflectance of organic EL devices having no color filter (organic EL devices shown in Fig. 4).

In Fig. 20, B indicates external light reflection of an organic EL device for emission of the blue (B) color, G indicates external light reflection of an organic EL

device for emission of the green (G) color, and R indicates external light reflection of an organic EL device for emission of the red (R) color. As shown in Fig. 20, any of these organic EL devices limits the reflectance of external light near the peak wavelength  $\lambda$  of each corresponding emission color to a low value. That is, in the organic EL device for blue color emission, reflection of external light in the blue (B) region is low. Similarly, in the organic EL device for red color emission and green color emission, reflectance of external light in their respective target wavelength regions is prevented.

Fig. 21 shows transmission properties of color filters (20R, 20G, 20B) disposed in respective organic EL devices. In Fig. 21, B indicates transmission property of the organic EL device for emission of the blue (B) color, G indicates transmission property of the organic EL device for emission of the green (G) color, and R indicates transmission property of the organic EL device for emission of the red (R) color. As shown in Fig. 21, in any of the color filters, transmittance is high near the peak wavelength  $\lambda$  of each emission color.

In case the external light reflectance of the organic EL device shown in Fig. 4 having no color filter is  $R(\lambda)$  and transmittance of the a color filter is  $T(\lambda)$ , external light reflectance  $R_t(\lambda)$  of the

organic EL device shown in Fig 19 having the color filter is expressed by the following equation (16).

$$R_t(\lambda) = T(\lambda) \times R(\lambda) \times T(\lambda) \quad (16)$$

Shown in Fig. 22 is a result of simulation as the external light reflectance of the organic EL device shown in Fig. 19, combining the graphs of Figs. 20 and 21 on the basis of Equation (16). In Fig. 22, B indicated external light reflection of the organic EL device for blue (B) color emission, G indicates external light reflection of the organic EL device for green (color) emission, and R indicates external light reflection of the organic EL device of green (G) color emission. As shown in Fig. 22, in any of the organic EL devices, reflectance of external light is limited to a low value in a wide wavelength region containing the peak wavelength  $\lambda$  of each emission color.

On the other hand, among the emission light generated in the organic layer 13, light h near the peak wavelength  $\lambda$  to be extracted directly passes through the narrow-band-pass filter (organic layer 13) and further through the color filter 20, and it is extracted as display light. Therefore, luminance of the emission light generated in the organic EL device is restricted exclusively by the transmittance of the color filter. However, each organic EL device has the color filter having a high transmittance to light near the peak wavelength  $\lambda$  to be extracted from emission

light generated in the organic EL device. Therefore,  
the decrease of the extraction efficiency of emission  
light due to the use of the color filter can be  
minimized, and the decrease of luminance can be  
minimized.

As a result, the organic EL device can  
prevent reflection of external light H containing light  
near the peak wavelength  $\lambda$  to be extracted without  
preventing extraction of light h near the peak  
wavelength  $\lambda$  to be extracted among the emission light.  
Therefore, contrast under external light can be  
improved significantly while ensuring sufficient  
luminance of the emission light.

In addition to that, in the organic EL  
device, since the wavelength range to be extracted  
after resonation in the organic layer 13 coincides with  
the wavelength range in which each color filter 20  
exhibits a high transmittance, reflection of external  
light  $H_1$  in the wavelength range passing through the  
color filter 20 can be prevented effectively in the  
organic layer 13.

Furthermore, similarly to the first  
embodiment, while inducing multiple interference of  
light h extracted from the organic EL device, its  
spectral width can be maintained in a certain width.  
Therefore, color purity can be improved in a wide view  
angle range.

The fourth embodiment has been explained, taking the organic EL device having the color filter in addition to the top surface emission type organic EL device according to the first embodiment shown in Fig.

5 4. The invention, however, is not limited to it, but can be also embodied to include the color filter in each of organic EL devices of configurations explained in the first, second and third embodiments. In any case, the color filter has the above-explained transmittance property.

10 In organic EL devices additionally having a color filter to respective configurations explained in the second embodiment, contrast under external light can be improved significantly while ensuring a sufficient luminance of emission light similarly to the statement already made, and at the same time, the same effect as the second embodiment, i.e. common use of the optical path length  $L$  in cavity portions for different emission colors, can be also obtained.

15 20 Further, In organic EL devices additionally having the color filter to configurations explained in the third embodiments, contrast under external light can be improved significantly while ensuring a sufficient luminance of emission light similarly to the statement already made, and simultaneously, the same effect as the third embodiment, i.e. improvement of color purity in a wider view angle range, can be also



obtained.

In case of using the organic EL devices according to the fourth embodiment also to an organic EL device configured to extract emission light through the substrate, the second electrode 32 of a transparent material, semitransparent reflection layer 33 serving as the anode electrode as well, organic layer 34 made up of the buffer layer 34a, hole transport layer 34b and organic light emitting layer 34c, and first electrode 35 that is the cathode electrode serving as the reflection layer as well are sequentially stacked on the transparent substrate as shown in Fig. 23, for example, and an appropriately selected color filter 20 is disposed in combination on the other surface of the transparent substrate 31. Alternatively, the color filter 20 may be disposed between the transparent substrate 31 and the second electrode 32.

As explained above, according to the display device recited in claim 1 of the invention, the cavity structure is optimized such that, while maintaining a certain spectral width of light extracted from emission light, intensity of the peak wavelength  $\lambda$  of that light by multiple interference. Therefore, a display device limited in shifting of the wavelength  $\lambda$  of the extracted light and improved in color impurity can be obtained in a wider view angle range. As a result, a display apparatus using this display device can be

enlarged in color reproduction range over a wide view angle range.

According to the display device recited in claim 2, emission light of each of wavelengths corresponding to red (R), green (G) and blue (B) can resonate in a common cavity portion. Therefore, optical path length need not specifically determined for each cavity portion of each display device for emission of a specific color, that is, a common optical path length L can be used in all cavity portions.

According to the display device recited in claim 3, it is possible to bring about multiple interference of emission light of a large number of peak wavelengths in respective red (R), green (G) and blue (B) regions in a common cavity portion.

Therefore, optical path length need not specifically determined for each cavity portion of each display device for emission of a specific color, that is, a common optical path length L can be used in all cavity portions. Moreover, since each extracted light of each color result in having a plurality of fine peaks, entire spectral width of each light can be increased. Therefore, a display device limited in shifting of the wavelength  $\lambda$  of the extracted light and improved in color impurity can be obtained in a wider view angle range. As a result, a display apparatus using this display device can be enlarged in color reproduction

range over a wide view angle range.

According to the display device recited in claim 4, because of the use of the combination of the cavity structure and the color filter, it is possible to prevent reflection of external light in all wavelength ranges containing light of a wavelength to be extracted without preventing radiation of part of emission light corresponding to the target wavelength. Therefore, contrast under external light can be improved significantly while keeping a sufficient luminance of emission light.

## CLAIMS

1. A display device having a light emitting layer interposed between a first electrode of a light reflective material and a second electrode of a transparent material and so configured that at least one of said second electrode and said light emitting layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians,  $L$  is optical path length of said cavity portion, and  $\lambda$  is the peak wavelength of the spectrum of part of light to be extracted, optical path length  $L$  of said cavity portion takes a positive minimum value in a range satisfying the equation:

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (m is an integer)}$$

2. A display device having a light emitting layer interposed between a first electrode of a light reflective material and a second electrode of a transparent material and so configured that at least one of said second electrode and said light emitting layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting

layer, characterized in that:

when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians,  $L'$  is optical path length of said cavity portion, and  $\lambda$  is the peak wavelength of the spectrum of green light, optical path length  $L'$  of said cavity portion is determined to satisfy the equation:

$$-(2L')/\lambda + \Phi/(2\pi) = m_1 + 4$$

which is made by adding 4 to the integer  $m_1$  that is one of integers  $m$  satisfying the equation:

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (} m \text{ is an integer)}$$

with which  $L$  takes a positive minimum value.

3. A display device having a light emitting layer interposed between a first electrode of a light reflective material and a second electrode of a transparent material and so configured that at least one of said second electrode and said light emitting layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians,  $L'$  is optical path length of said cavity portion, and  $\lambda$  is the peak wavelength of the spectrum of green light,

optical path length  $L'$  of said cavity portion is determined to satisfy the equation:

$$(2L')/\lambda + \Phi/(2\pi) = m_1 + q$$

which is made by adding an integer not smaller than 10  
5 to the integer  $m_1$  that is one of integers  $m$  satisfying the equation:

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (} m \text{ is an integer)}$$

with which  $L$  takes a positive minimum value.

10 4. A display device having a light emitting layer interposed between a first electrode of a light reflective material and a second electrode of a transparent material and so configured that at least one of said second electrode and said light emitting  
15 layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

a color filter for transmitting light which resonates in said cavity portion and is to be extracted  
20 through said second electrode is provided above said second electrode.

25 5. A display device having a light emitting layer interposed between a first electrode of a light reflective material and a second electrode of a transparent material and so configured that at least one of said second electrode and said light emitting

layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

5 a color filter for transmitting light which resonates in said cavity portion and is to be extracted through said second electrode is provided above said second electrode; and

10 when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians,  $L$  is optical path length of said cavity portion, and  $\lambda$  is the peak wavelength of the spectrum of part of light to be extracted, optical path length  $L$  of said cavity portion takes a positive minimum value in a range satisfying the equation:

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (m is an integer)}$$

15 with which  $L$  takes a positive minimum value.

6. A display device having a light emitting layer interposed between a first electrode of a light reflective material and a second electrode of a transparent material and so configured that at least one of said second electrode and said light emitting layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

20 a color filter for transmitting light which

resonates in said cavity portion and is to be extracted through said second electrode is provided above said second electrode; and

when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians,  $L'$  is optical path length of said cavity portion, and  $\lambda$  is the peak wavelength of the spectrum of green light, optical path length  $L'$  of said cavity portion is determined to satisfy the equation:

$$(2L')/\lambda + \Phi/(2\pi) = m_1 + 4$$

which is made by adding 4 to the integer  $m_1$  that is one of integers  $m$  satisfying the equation:

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (} m \text{ is an integer)}$$

with which  $L$  takes a positive minimum value.

7. A display device having a light emitting layer interposed between a first electrode of a light reflective material and a second electrode of a transparent material and so configured that at least one of said second electrode and said light emitting layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

a color filter for transmitting light which resonates in said cavity portion and is to be extracted through said second electrode is provided above said



second electrode; and

when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians,  $L'$  is optical path length of said cavity portion, and  $\lambda$  is the peak wavelength of the spectrum of green light, optical path length  $L'$  of said cavity portion is determined to satisfy the equation:

$$(2L')/\lambda + \Phi/(2\pi) = m_1 + q$$

which is made by adding an integer not smaller than 10 to the integer  $m_1$  that is one of integers  $m$  satisfying the equation:

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (} m \text{ is an integer)}$$

with which  $L$  takes a positive minimum value.

8. A display device having a light emitting layer between a first electrode and a second electrode such that at least one of said light emitting layer and one of said first electrodes and said second electrodes permitting light to be extracted therethrough functions as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians,  $L$  is optical path length of said cavity portion, and  $\lambda$  is

the peak wavelength of the spectrum of part of light to be extracted, optical path length L of said cavity portion takes a positive minimum value in a range satisfying the equation:

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (m is an integer)}$$

9. A display device having a light emitting layer between a first electrode and a second electrode such that at least one of said light emitting layer and one of said first electrodes and said second electrodes permitting light to be extracted therethrough functions as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians, L' is optical path length of said cavity portion, and  $\lambda$  is the peak wavelength of the spectrum of green light, optical path length L' of said cavity portion is determined to satisfy the equation:

$$(2L')/\lambda + \Phi/(2\pi) = m_1 + 4$$

which is made by adding 4 to the integer  $m_1$  that is one of integers m satisfying the equation:

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (m is an integer)}$$

with which L takes a positive minimum value.

10. A display device having a light emitting layer between a first electrode and a second electrode such that at least one of said light emitting layer and one of said first electrodes and said second electrodes permitting light to be extracted therethrough functions as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians,  $L'$  is optical path length of said cavity portion, and  $\lambda$  is the peak wavelength of the spectrum of green light, optical path length  $L'$  of said cavity portion is determined to satisfy the equation:

$$(2L')/\lambda + \Phi/(2\pi) = m_1 + q$$

which is made by adding an integer not smaller than 10 to the integer  $m_1$  that is one of integers  $m$  satisfying the equation:

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (} m \text{ is an integer)}$$

with which  $L$  takes a positive minimum value.

11. A display device having a light emitting layer between a first electrode and a second electrode such that at least one of said light emitting layer and one of said first electrodes and said second electrodes permitting light to be extracted therethrough functions

as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

5 a color filter for transmitting light which resonates in said cavity portion and is to be extracted through said second electrode is provided above one of said first electrode and said second electrode, through which light is to be extracted.

10 12. A display device having a light emitting layer between a first electrode and a second electrode such that at least one of said light emitting layer and one of said first electrodes and said second electrodes permitting light to be extracted therethrough functions  
15 as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

20 a color filter for transmitting light which resonates in said cavity portion and is to be extracted through said second electrode is provided above one of said first electrode and said second electrode, through which light is to be extracted; and

25 when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians,  $L$  is optical path length of said cavity portion, and  $\lambda$  is the peak wavelength of the spectrum of part of light to

be extracted, optical path length L of said cavity portion takes a positive minimum value in a range satisfying the equation:

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (m is an integer)}$$

13. A display device having a light emitting layer between a first electrode and a second electrode such that at least one of said light emitting layer and one of said first electrodes and said second electrodes permitting light to be extracted therethrough functions as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

a color filter for transmitting light which resonates in said cavity portion and is to be extracted through said second electrode is provided above one of said first electrode and said second electrode, through which light is to be extracted; and

when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians,  $L'$  is optical path length of said cavity portion, and  $\lambda$  is the peak wavelength of the spectrum of green light, optical path length  $L'$  of said cavity portion is determined to satisfy the equation:

$$(2L')/\lambda + \Phi/(2\pi) = m_1 + 4$$

which is made by adding 4 to the integer  $m_1$  that is one

of integers  $m$  satisfying the equation:

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (} m \text{ is an integer)}$$

with which  $L$  takes a positive minimum value.

5 14. A display device having a light emitting layer between a first electrode and a second electrode such that at least one of said light emitting layer and one of said first electrodes and said second electrodes permitting light to be extracted therethrough functions as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

10 a color filter for transmitting light which resonates in said cavity portion and is to be extracted through said second electrode is provided above one of said first electrode and said second electrode, through which light is to be extracted; and

15 when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians,  $L'$  is optical path length of said cavity portion, and  $\lambda$  is the peak wavelength of the spectrum of green light, optical path length  $L'$  of said cavity portion is determined to satisfy the equation:

20 
$$(2L')/\lambda + \Phi/(2\pi) = m_1 + q$$

25 which is made by adding an integer not smaller than 10 to the integer  $m_1$  that is one of integers  $m$  satisfying

the equation:

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (m is an integer)}$$

with which L takes a positive minimum value.

5 15. A display device having a first electrode, a  
light emitting layer and a second electrode of a  
transparent material sequentially stacked on a  
substrate and so configured that at least one of said  
second electrode and said light emitting layer serves  
10 as a cavity portion of a cavity structure for  
resonating light emitted in said light emitting layer,  
characterized in that:

when the phase shift produced in light  
generated in said light emitting layer when reflected  
by opposite ends of said cavity portion is  $\Phi$  radians, L  
15 is optical path length of said cavity portion, and  $\lambda$  is  
the peak wavelength of the spectrum of part of light to  
be extracted, optical path length L of said cavity  
portion takes a positive minimum value in a range  
20 satisfying the equation:

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (m is an integer)}$$

16. A display device having a first electrode, a  
light emitting layer and a second electrode of a  
25 transparent material sequentially stacked on a  
substrate and so configured that at least one of said  
second electrode and said light emitting layer serves

as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians,  $L'$  is optical path length of said cavity portion, and  $\lambda$  is the peak wavelength of the spectrum of green light, optical path length  $L'$  of said cavity portion is determined to satisfy the equation:

$$(2L')/\lambda + \Phi/(2\pi) = m_1 + 4$$

which is made by adding 4 to the integer  $m_1$  that is one of integers  $m$  satisfying the equation:

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (} m \text{ is an integer)}$$

with which  $L$  takes a positive minimum value.

17. A display device having a first electrode, a light emitting layer and a second electrode of a transparent material sequentially stacked on a substrate and so configured that at least one of said second electrode and said light emitting layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians,



L' is optical path length of said cavity portion, and  $\lambda$  is the peak wavelength of the spectrum of green light, optical path length L' of said cavity portion is determined to satisfy the equation:

$$(2L')/\lambda + \Phi/(2\pi) = m_1 + q$$

which is made by adding an integer not smaller than 10 to the integer  $m_1$  that is one of integers  $m$  satisfying the equation:

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (m is an integer)}$$

with which L takes a positive minimum value.

18. A display device having a first electrode, a light emitting layer and a second electrode of a transparent material sequentially stacked on a substrate and so configured that at least one of said second electrode and said light emitting layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

a color filter for transmitting light which resonates in said cavity portion and is to be extracted through said second electrode is provided above said second electrode.

19. A display device having a first electrode, a light emitting layer and a second electrode of a transparent material sequentially stacked on a

substrate and so configured that at least one of said second electrode and said light emitting layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

a color filter for transmitting light which resonates in said cavity portion and is to be extracted through said second electrode is provided above said second electrode; and

when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians,  $L$  is optical path length of said cavity portion, and  $\lambda$  is the peak wavelength of the spectrum of part of light to be extracted, optical path length  $L$  of said cavity portion takes a positive minimum value in a range satisfying the equation:

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (m is an integer)}$$

20. A display device having a first electrode, a light emitting layer and a second electrode of a transparent material sequentially stacked on a substrate and so configured that at least one of said second electrode and said light emitting layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

a color filter for transmitting light which resonates in said cavity portion and is to be extracted through said second electrode is provided above said second electrode; and

5 when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians,  $L'$  is optical path length of said cavity portion, and  $\lambda$  is the peak wavelength of the spectrum of green light, optical path length  $L'$  of said cavity portion is  
10 determined to satisfy the equation:

$$(2L')/\lambda + \Phi/(2\pi) = m1 + 4$$

which is made by adding 4 to the integer  $m1$  that is one of integers  $m$  satisfying the equation:

15 
$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (m is an integer)}$$

with which  $L$  takes a positive minimum value.

21. A display device having a first electrode, a light emitting layer and a second electrode of a  
20 transparent material sequentially stacked on a substrate and so configured that at least one of said second electrode and said light emitting layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer,  
25 characterized in that:

a color filter for transmitting light which resonates in said cavity portion and is to be extracted

through said second electrode is provided above said second electrode; and

when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians,  $L'$  is optical path length of said cavity portion, and  $\lambda$  is the peak wavelength of the spectrum of green light, optical path length  $L'$  of said cavity portion is determined to satisfy the equation:

$$(2L')/\lambda + \Phi/(2\pi) = m_1 + q$$

which is made by adding an integer not smaller than 10 to the integer  $m_1$  that is one of integers  $m$  satisfying the equation:

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (} m \text{ is an integer)}$$

with which  $L$  takes a positive minimum value.

22. A display device having a first electrode, a light emitting layer and a second electrode of a transparent material sequentially stacked on a substrate and so configured that said light emitting layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians,  $L$  is optical path length of said cavity portion, and  $\lambda$  is

the peak wavelength of the spectrum of part of light to be extracted, optical path length L of said cavity portion takes a positive minimum value in a range satisfying the equation:

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (m is an integer)}$$

23. A display device having a first electrode, a light emitting layer and a second electrode of a transparent material sequentially stacked on a substrate and so configured that said light emitting layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians,  $L'$  is optical path length of said cavity portion, and  $\lambda$  is the peak wavelength of the spectrum of green light, optical path length  $L'$  of said cavity portion is determined to satisfy the equation:

$$(2L')/\lambda + \Phi/(2\pi) = m_1 + 4$$

which is made by adding 4 to the integer  $m_1$  that is one of integers  $m$  satisfying the equation:

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (m is an integer)}$$

with which L takes a positive minimum value.

24. A display device having a first electrode, a

light emitting layer and a second electrode of a transparent material sequentially stacked on a substrate and so configured that said light emitting layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians,  $L'$  is optical path length of said cavity portion, and  $\lambda$  is the peak wavelength of the spectrum of green light, optical path length  $L'$  of said cavity portion is determined to satisfy the equation:

$$(2L')/\lambda + \Phi/(2\pi) = m_1 + q$$

which is made by adding an integer not smaller than 10 to the integer  $m_1$  that is one of integers  $m$  satisfying the equation:

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (} m \text{ is an integer)}$$

with which  $L$  takes a positive minimum value.

25. A display device having a first electrode, a light emitting layer and a second electrode of a transparent material sequentially stacked on a substrate and so configured that said light emitting layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

a color filter for transmitting light which resonates in said cavity portion and is to be extracted through said second electrode is provided above said second electrode.

5

26. A display device having a first electrode, a light emitting layer and a second electrode of a transparent material sequentially stacked on a substrate and so configured that said light emitting layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

a color filter for transmitting light which resonates in said cavity portion and is to be extracted through said second electrode is provided above said second electrode; and

when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians,  $L$  is optical path length of said cavity portion, and  $\lambda$  is the peak wavelength of the spectrum of part of light to be extracted, optical path length  $L$  of said cavity portion takes a positive minimum value in a range satisfying the equation:

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (m is an integer)}$$

27. A display device having a first electrode, a

light emitting layer and a second electrode of a transparent material sequentially stacked on a substrate and so configured that said light emitting layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

a color filter for transmitting light which resonates in said cavity portion and is to be extracted through said second electrode is provided above said second electrode; and

when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians,  $L'$  is optical path length of said cavity portion, and  $\lambda$  is the peak wavelength of the spectrum of green light, optical path length  $L'$  of said cavity portion is determined to satisfy the equation:

$$(2L')/\lambda + \Phi/(2\pi) = m1 + 4$$

which is made by adding 4 to the integer  $m1$  that is one of integers  $m$  satisfying the equation:

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (} m \text{ is an integer)}$$

with which  $L$  takes a positive minimum value.

28. A display device having a first electrode, a light emitting layer and a second electrode of a transparent material sequentially stacked on a substrate and so configured that said light emitting



layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

5 a color filter for transmitting light which resonates in said cavity portion and is to be extracted through said second electrode is provided above said second electrode; and

10 when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians,  $L'$  is optical path length of said cavity portion, and  $\lambda$  is the peak wavelength of the spectrum of green light, optical path length  $L'$  of said cavity portion is determined to satisfy the equation:

15 
$$(2L')/\lambda + \Phi/(2\pi) = m_1 + q$$

which is made by adding an integer not smaller than 10 to the integer  $m_1$  that is one of integers  $m$  satisfying the equation:

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (} m \text{ is an integer)}$$

20 with which  $L$  takes a positive minimum value.

29. A display device having a first electrode, a light emitting layer and a second electrode of a transparent material sequentially stacked on a substrate and so configured that said second electrode serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer,

25

characterized in that:

when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians,  $L$  is optical path length of said cavity portion, and  $\lambda$  is the peak wavelength of the spectrum of part of light to be extracted, optical path length  $L$  of said cavity portion takes a positive minimum value in a range satisfying the equation:

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (m is an integer)}$$

30. A display device having a first electrode, a light emitting layer and a second electrode of a transparent material sequentially stacked on a substrate and so configured that said second electrode serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians,  $L'$  is optical path length of said cavity portion, and  $\lambda$  is the peak wavelength of the spectrum of green light, optical path length  $L'$  of said cavity portion is determined to satisfy the equation:

$$(2L')/\lambda + \Phi/(2\pi) = m_1 + 4$$

which is made by adding 4 to the integer  $m_1$  that is one

of integers m satisfying the equation:

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (m is an integer)}$$

with which L takes a positive minimum value.

5 31. A display device having a first electrode, a  
light emitting layer and a second electrode of a  
transparent material sequentially stacked on a  
substrate and so configured that said second electrode  
serves as a cavity portion of a cavity structure for  
10 resonating light emitted in said light emitting layer,  
characterized in that:

when the phase shift produced in light  
generated in said light emitting layer when reflected  
by opposite ends of said cavity portion is  $\Phi$  radians,  
15 L' is optical path length of said cavity portion, and  $\lambda$   
is the peak wavelength of the spectrum of green light,  
optical path length L' of said cavity portion is  
determined to satisfy the equation:

$$(2L')/\lambda + \Phi/(2\pi) = m_1 + q$$

20 which is made by adding an integer not smaller than 10  
to the integer  $m_1$  that is one of integers m satisfying  
the equation:

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (m is an integer)}$$

with which L takes a positive minimum value.

25 32. A display device having a first electrode, a  
light emitting layer and a second electrode of a

transparent material sequentially stacked on a substrate and so configured that said second electrode serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

a color filter for transmitting light which resonates in said cavity portion and is to be extracted through said second electrode is provided above said second electrode.

33. A display device having a first electrode, a light emitting layer and a second electrode of a transparent material sequentially stacked on a substrate and so configured that said second electrode serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

a color filter for transmitting light which resonates in said cavity portion and is to be extracted through said second electrode is provided above said second electrode; and

when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians,  $L$  is optical path length of said cavity portion, and  $\lambda$  is the peak wavelength of the spectrum of part of light to be extracted, optical path length  $L$  of said cavity

portion takes a positive minimum value in a range satisfying the equation:

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (m is an integer)}$$

5 34. A display device having a first electrode, a light emitting layer and a second electrode of a transparent material sequentially stacked on a substrate and so configured that said second electrode serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

10 a color filter for transmitting light which resonates in said cavity portion and is to be extracted through said second electrode is provided above said second electrode; and

15 when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians,  $L'$  is optical path length of said cavity portion, and  $\lambda$  is the peak wavelength of the spectrum of green light, optical path length  $L'$  of said cavity portion is determined to satisfy the equation:

$$(2L')/\lambda + \Phi/(2\pi) = m_1 + 4$$

20 which is made by adding 4 to the integer  $m_1$  that is one of integers  $m$  satisfying the equation:

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (m is an integer)}$$

25 with which  $L$  takes a positive minimum value.

35. A display device having a first electrode, a light emitting layer and a second electrode of a transparent material sequentially stacked on a substrate and so configured that said second electrode serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

a color filter for transmitting light which resonates in said cavity portion and is to be extracted through said second electrode is provided above said second electrode; and

when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is  $\Phi$  radians,  $L'$  is optical path length of said cavity portion, and  $\lambda$  is the peak wavelength of the spectrum of green light, optical path length  $L'$  of said cavity portion is determined to satisfy the equation:

$$(2L')/\lambda + \Phi/(2\pi) = m_1 + q$$

which is made by adding an integer not smaller than 10 to the integer  $m_1$  that is one of integers  $m$  satisfying the equation:

$$(2L)/\lambda + \Phi/(2\pi) = m \text{ (} m \text{ is an integer)}$$

with which  $L$  takes a positive minimum value.

36. A display device having a light emitting

layer interposed between a first electrode of a light reflective material and a second electrode of a transparent material and so configured that at least one of said second electrode and said light emitting layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

when optical path length of said cavity portion is L, said optical path length L is determined so determined that difference between the peak wavelength of the spectrum of light to be extracted upon a change in view angle and the peak wavelength of the internal emission spectrum is limited within one half of the half-width of said internal emission spectrum.

37. A display device having a light emitting layer interposed between a first electrode of a light reflective material and a second electrode of a transparent material and so configured that at least one of said second electrode and said light emitting layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, characterized in that:

a color filter for transmitting light which resonates in said cavity portion and is to be extracted through said second electrode is provided above said

second electrode; and

when optical path length of said cavity  
portion is  $L$ , said optical path length  $L$  is determined  
so determined that difference between the peak  
5 wavelength of the spectrum of light to be extracted  
upon a change in view angle and the peak wavelength of  
the internal emission spectrum is limited within one  
half of the half-width of said internal emission  
spectrum.

10



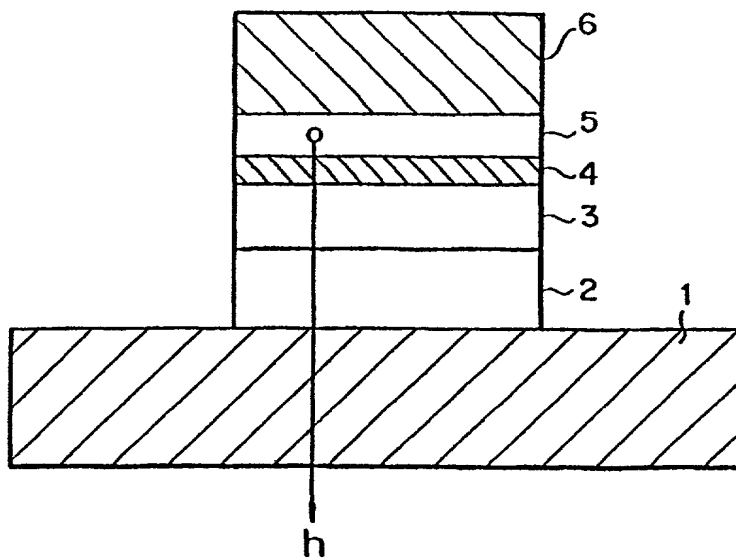
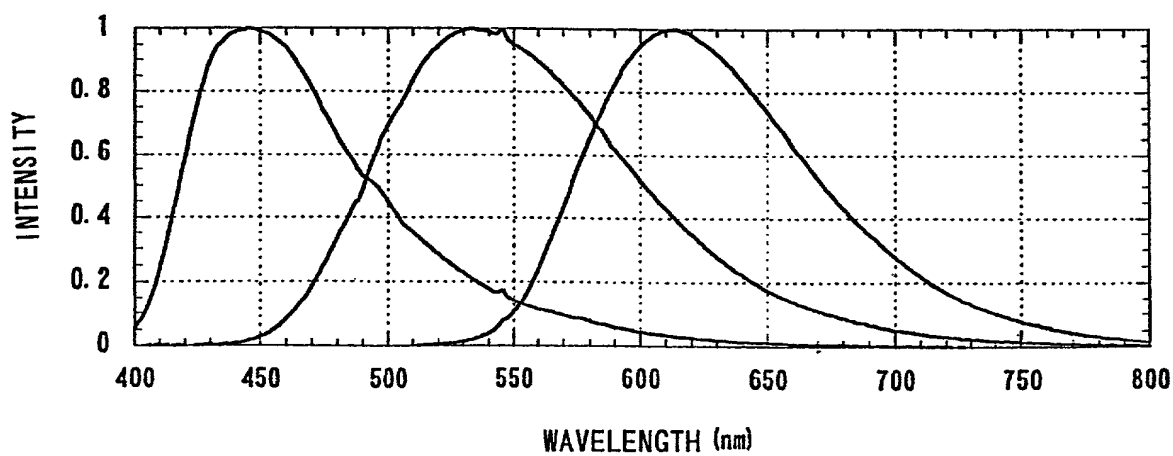
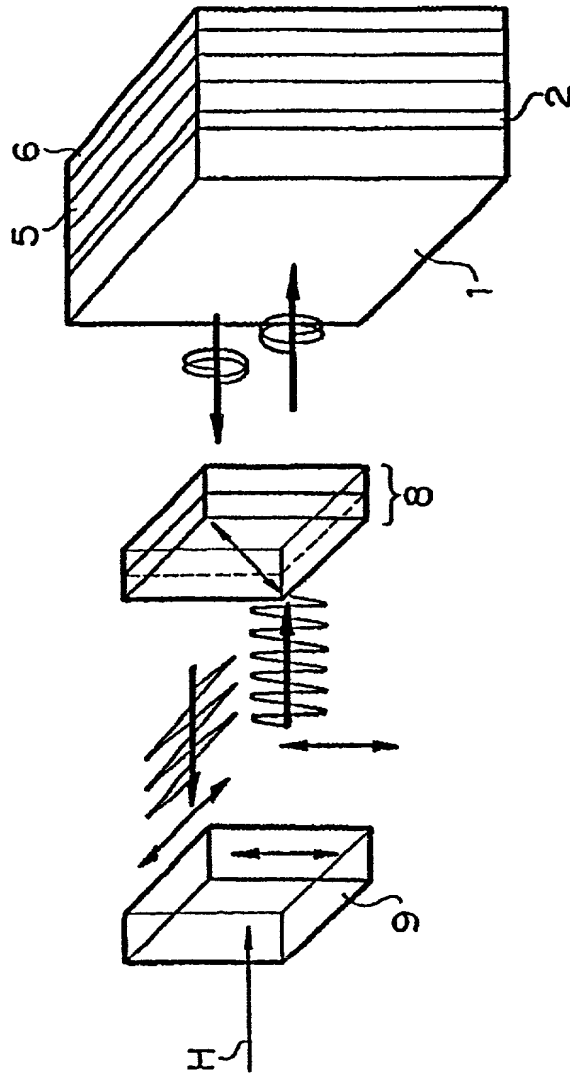
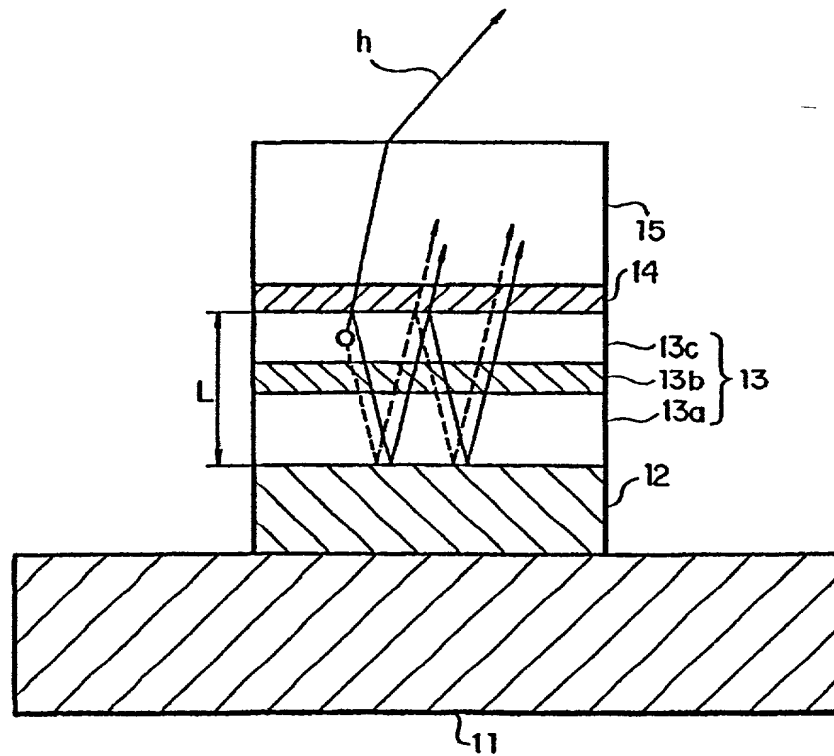
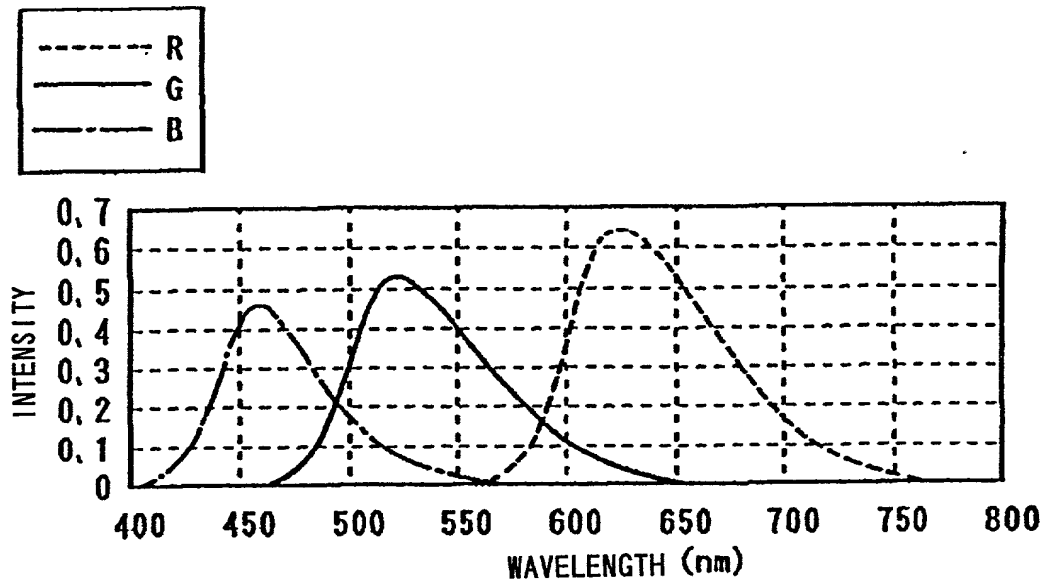
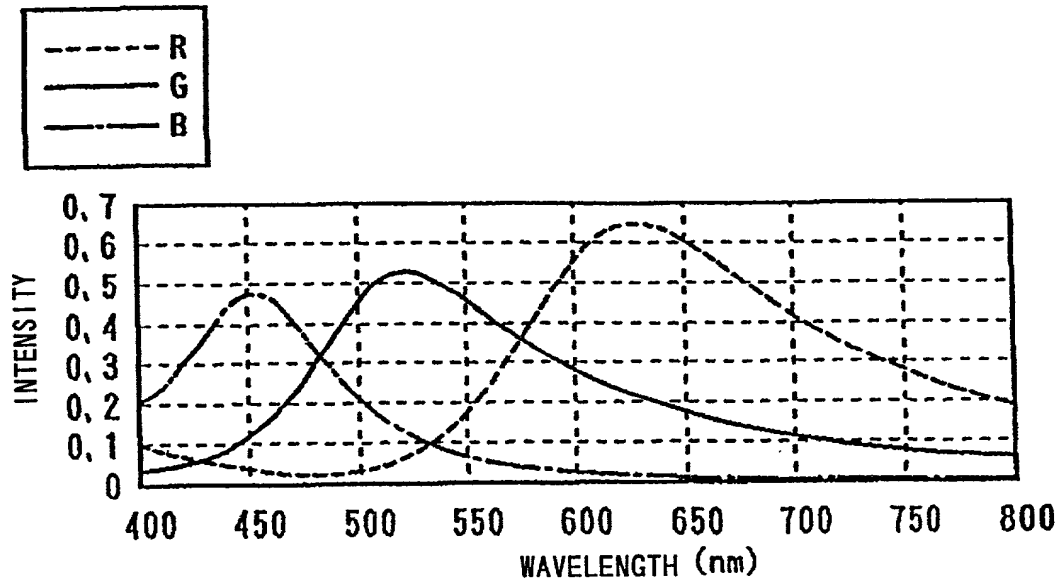
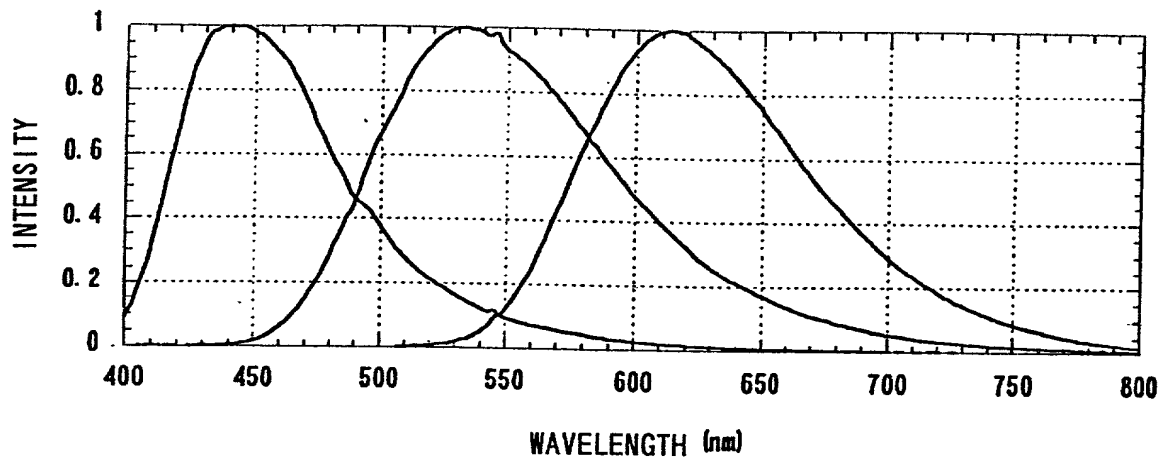
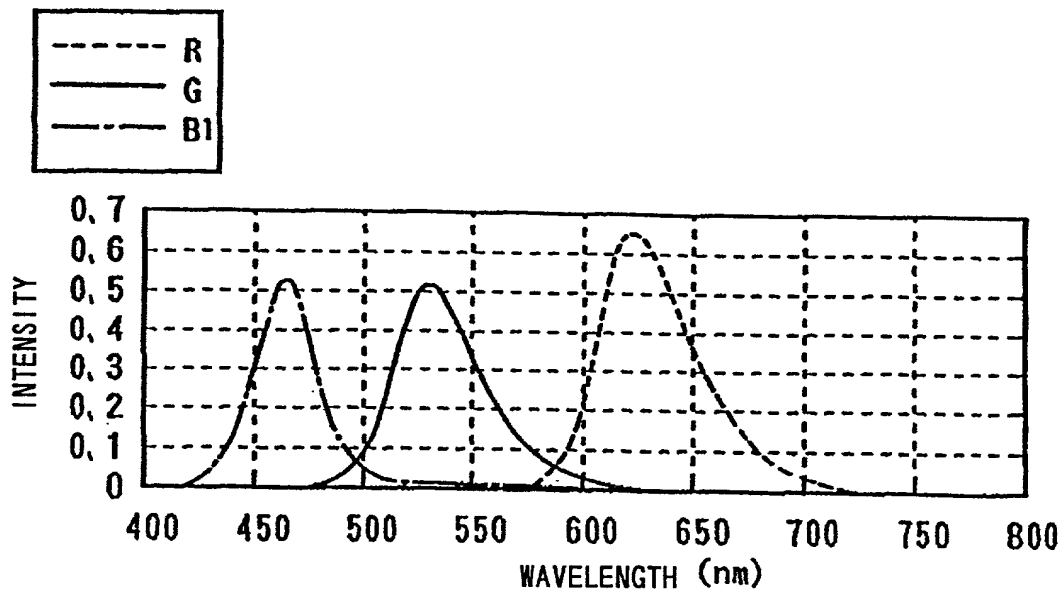
*Fig. 1**Fig. 2*

Fig. 3



*Fig. 4*

*Fig. 5**Fig. 6*

*Fig. 7**Fig. 8*

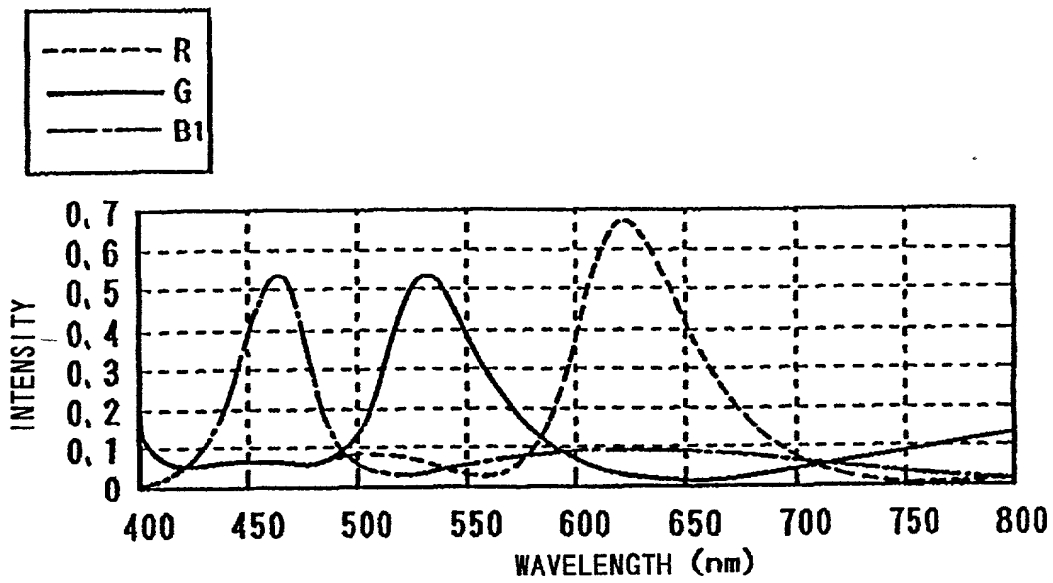
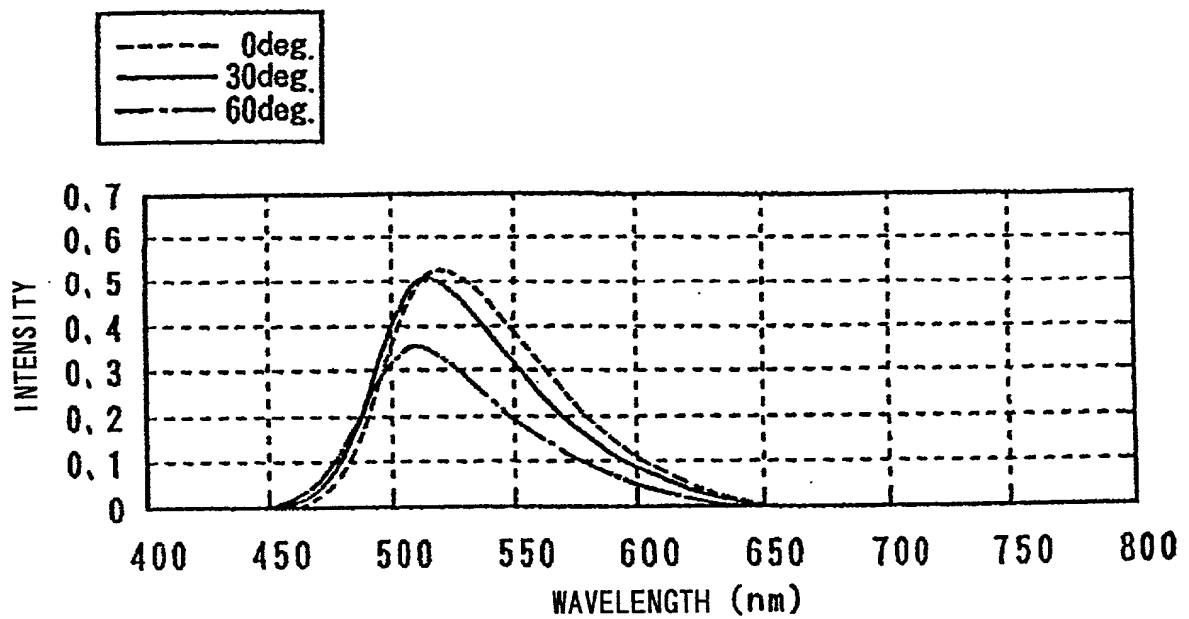
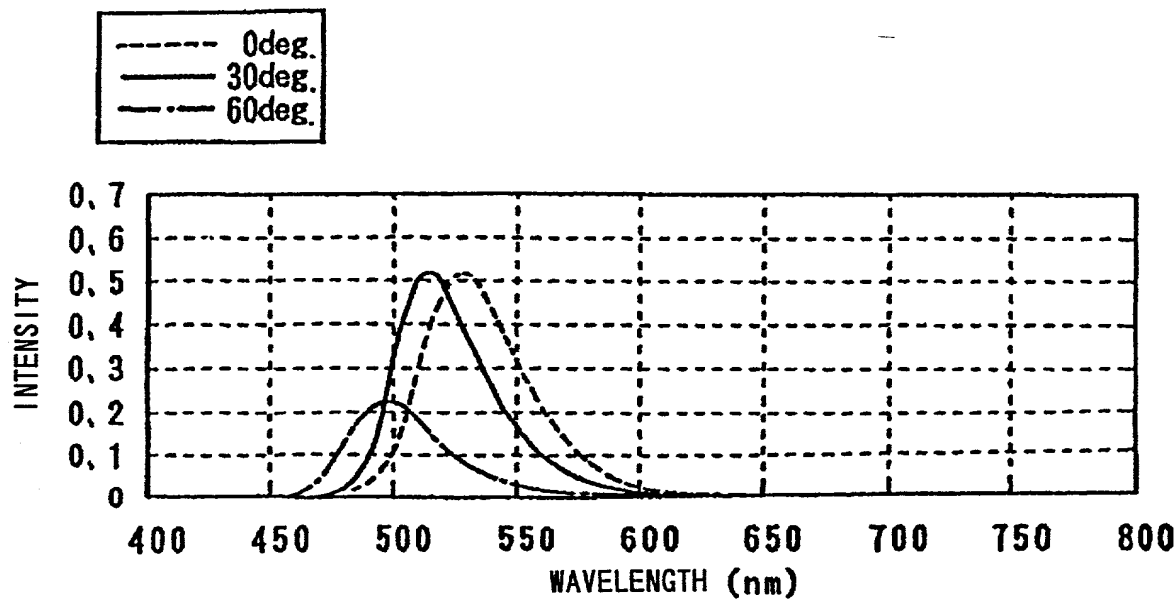
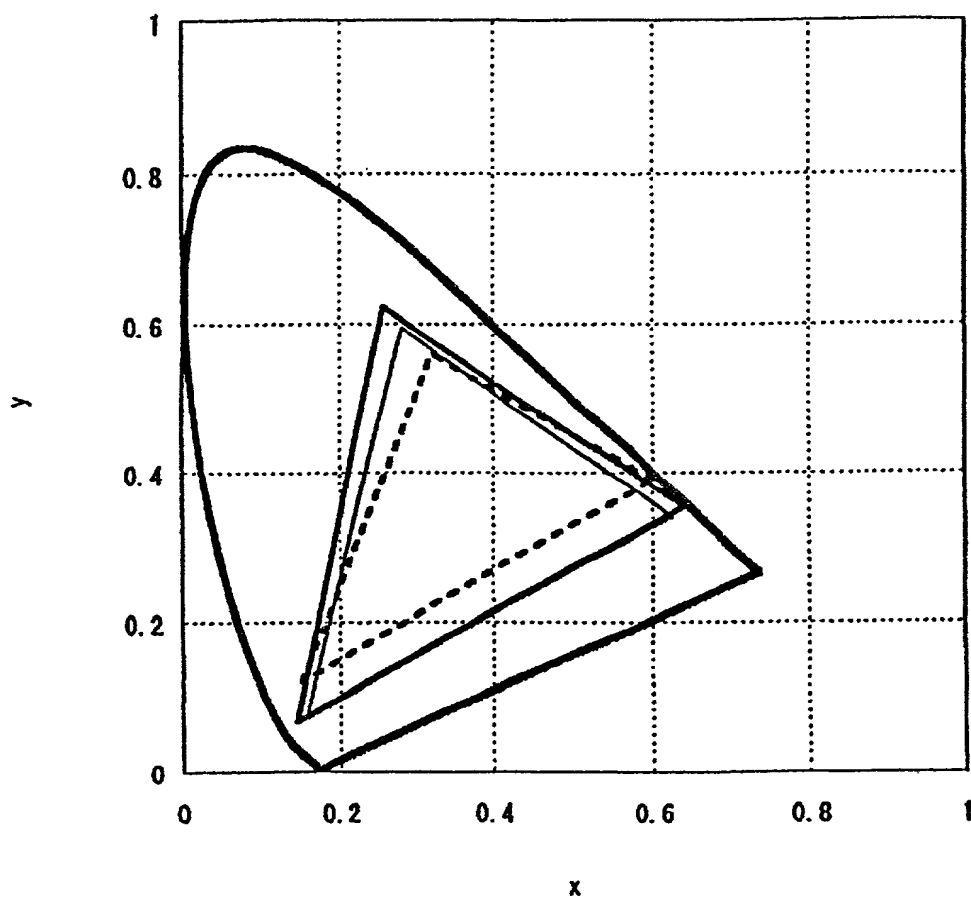
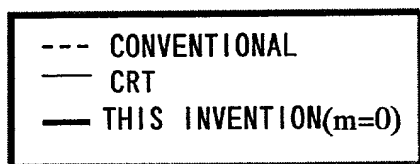
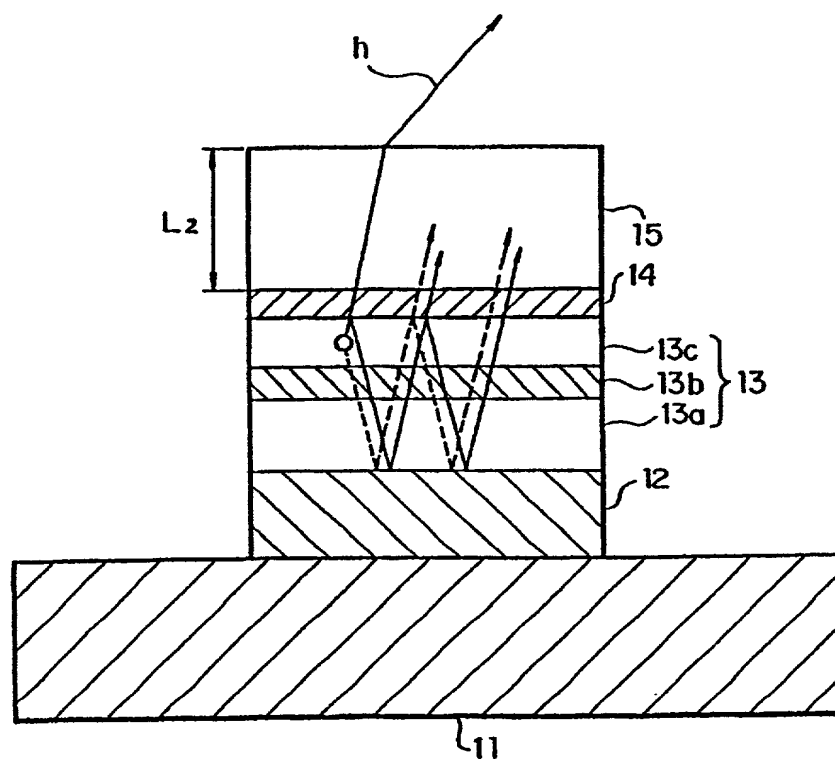
*Fig. 9**Fig. 10*

Fig. 11

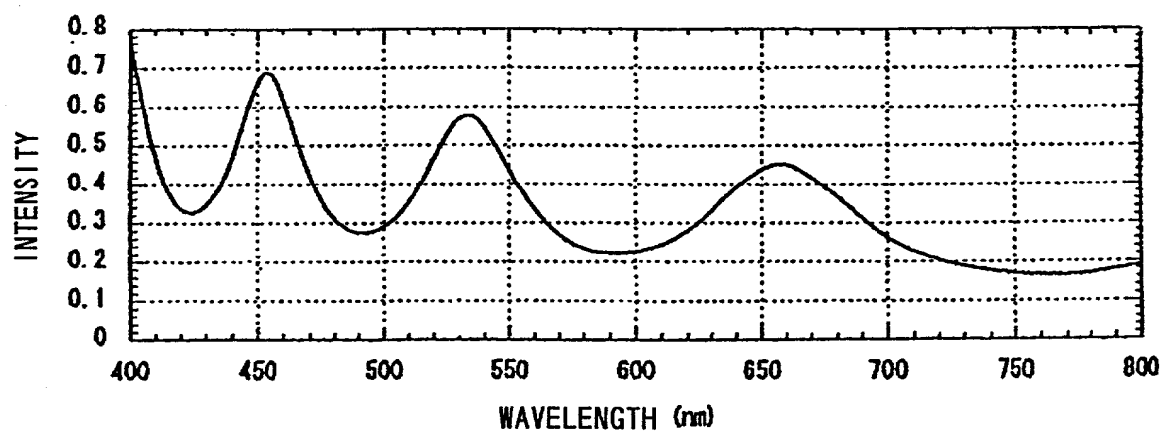


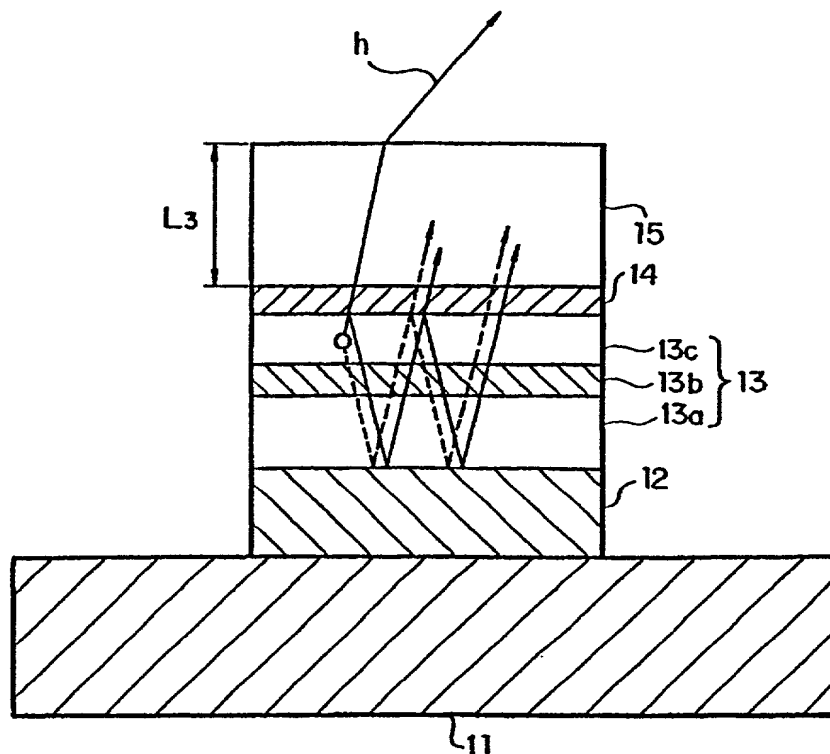
*Fig. 12*

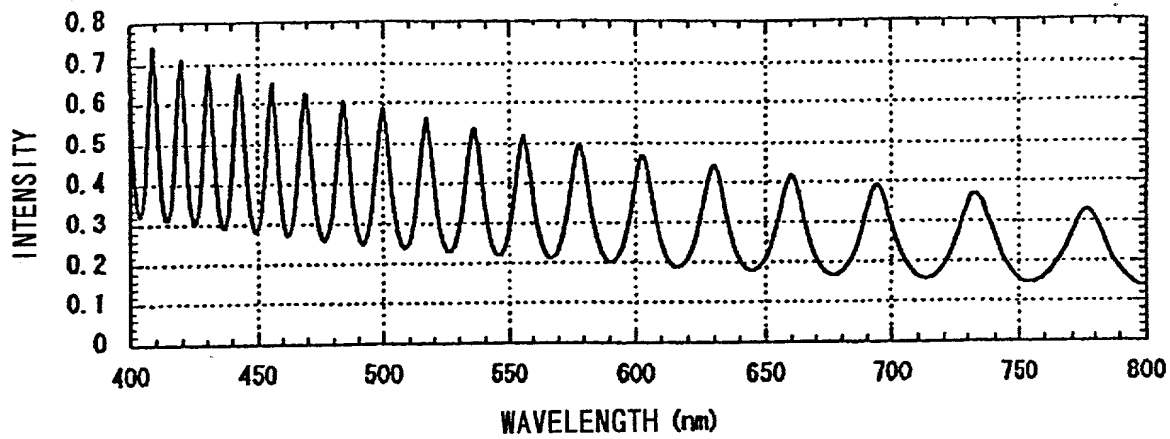
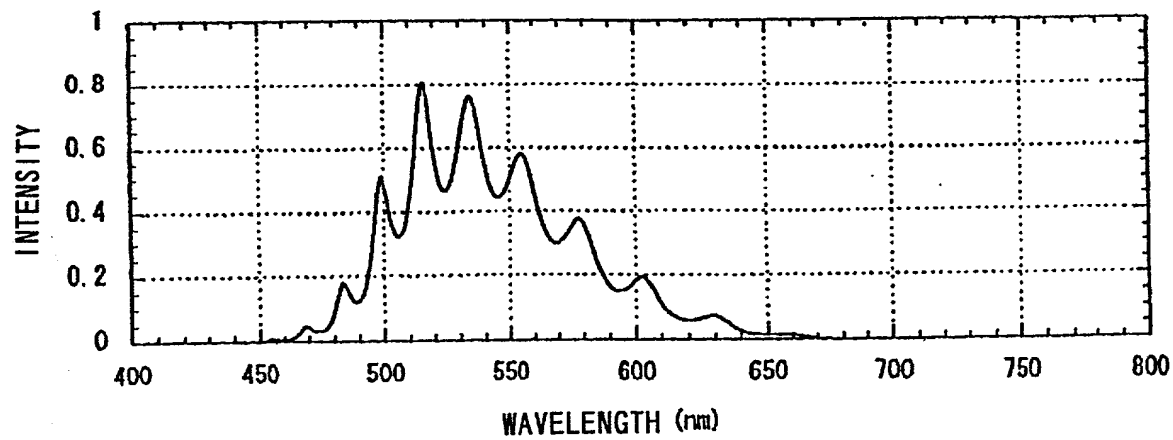


*Fig. 13*

*Fig. 14*



*Fig. 15*

*Fig. 16**Fig. 17*

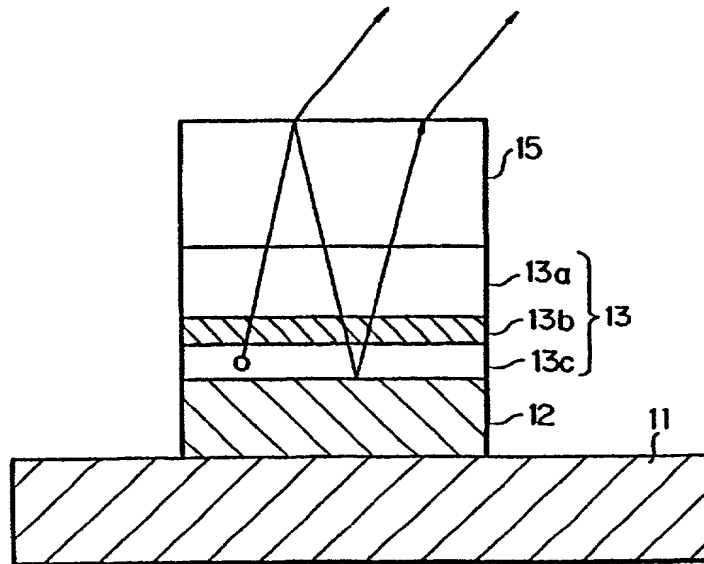
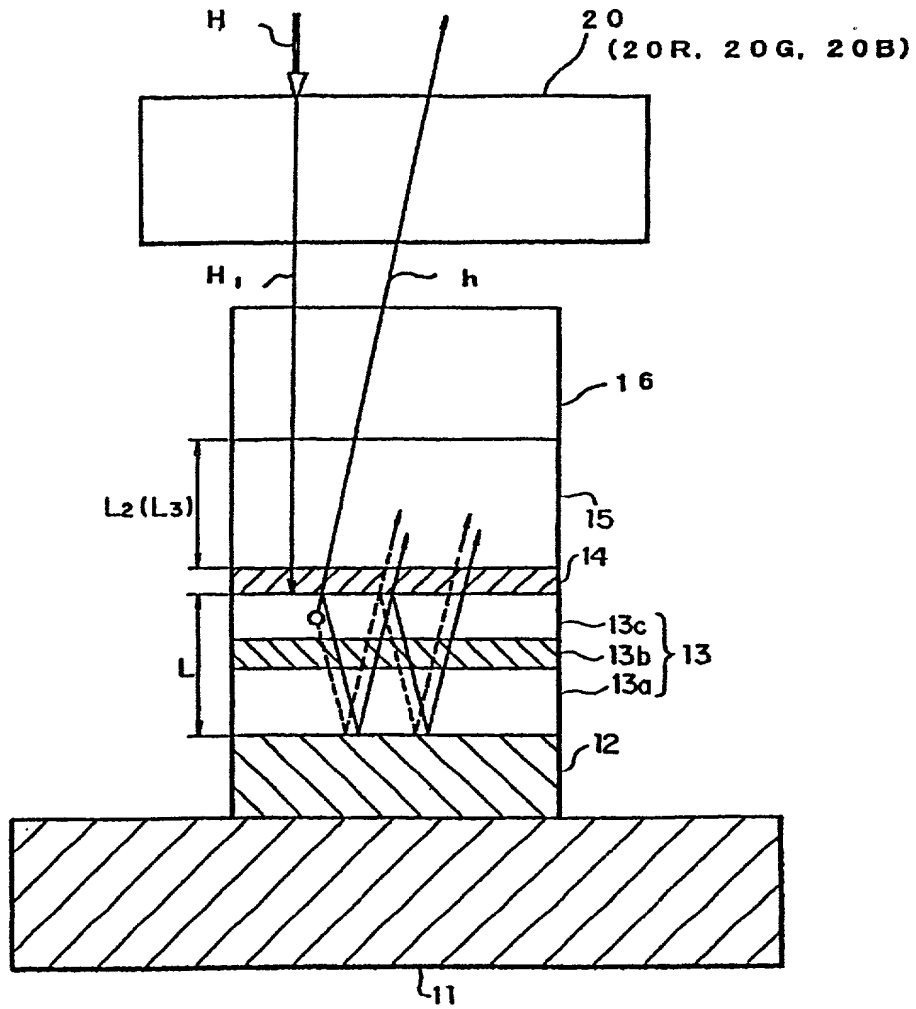
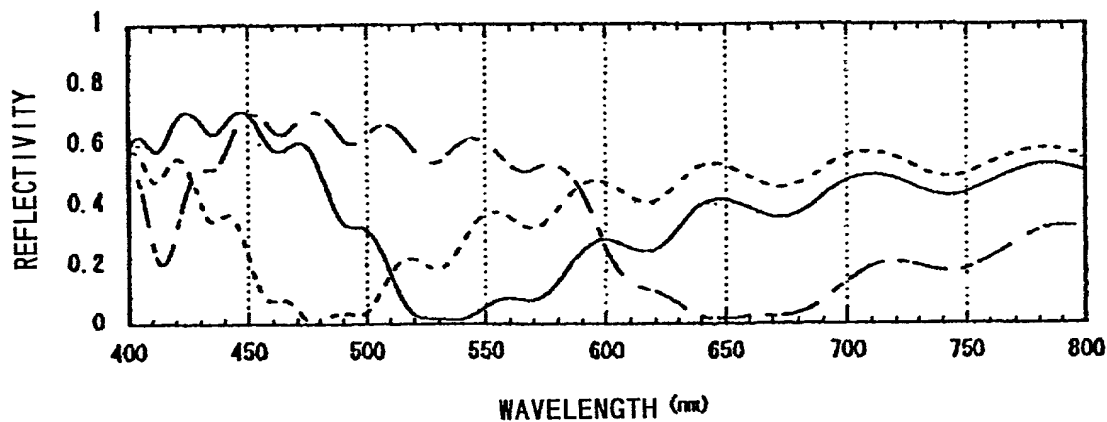
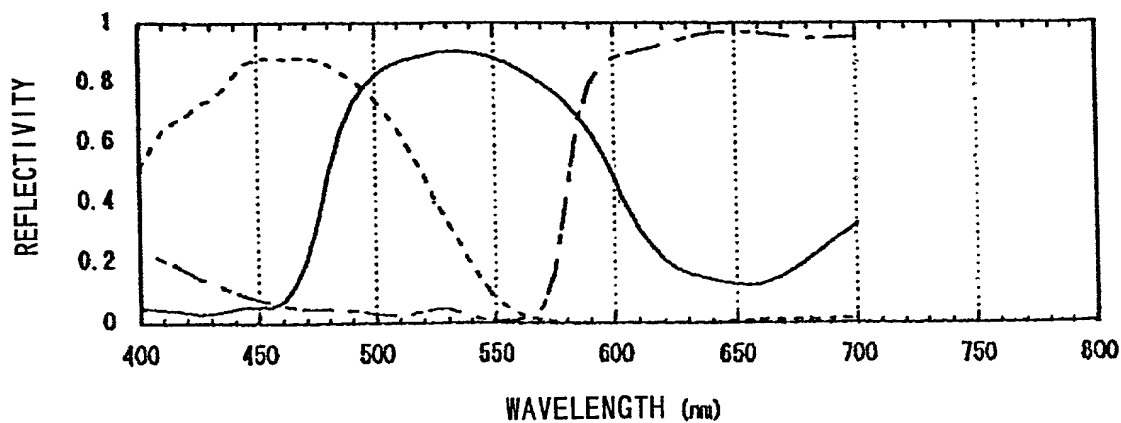
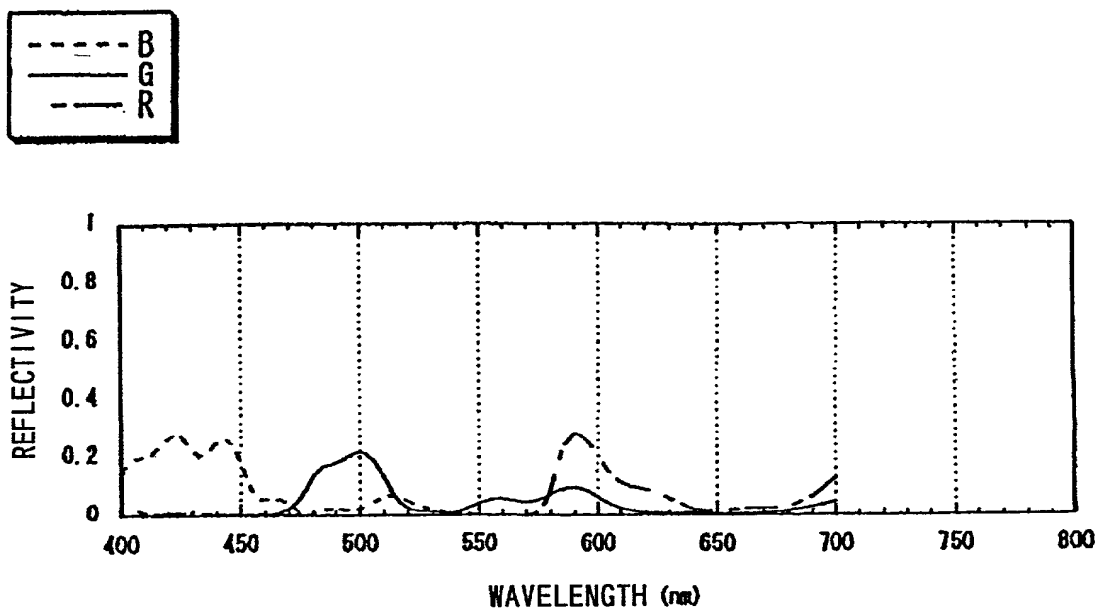
*Fig. 18*

Fig. 19

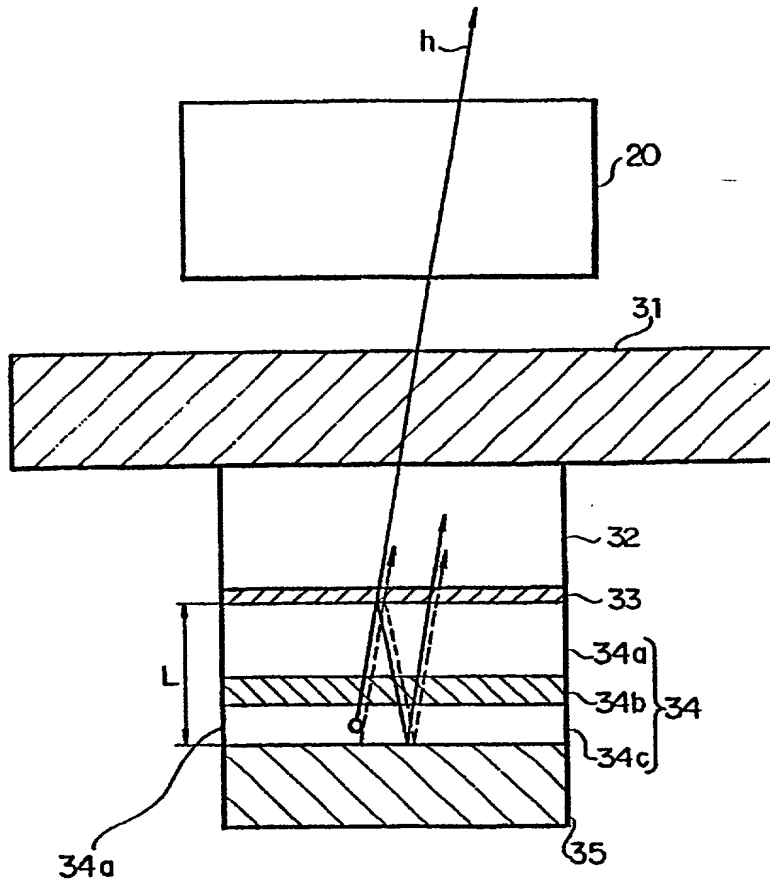


*Fig. 20**Fig. 21*

*Fig. 22*





*Fig. 23*

## DESCRIPTION OF REFERENCE NUMERALS

12, 35	FIRST ELECTRODE
13, 34	ORGANIC LAYER
13c, 34c	ORGANIC LIGHT EMITTING LAYER
14, 33	SEMITRANSSPARENT REFLECTION LAYER
15, 32	SECOND ELECTRODE
20	COLOR FILTER

特許出願宣言書及び委任状

Japanese Language Declaration

日本語宣言書



ATTORNEY DOCKET NO. 09794353-0017

下記の氏名の発明者として、私は以下の通り宣言します。

私の住所、私書箱、国籍は下記の私の氏名の後に記載された通りです。

下記の名称の発明に関して請求範囲に記載され、特許出願している発明内容について、私が最初かつ唯一の発明者（下記の氏名が一つの場合）もしくは最初かつ共同発明者であると（下記の名称が複数の場合）信じています。

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

“DISPLAY DEVICE”

上記発明の明細書（下記の欄でx印がついていない場合は、本書に添付）は、

the specification of which is attached hereto unless the following box is checked:

☐ 月 日に提出され、米国出願番号または特許協定条約国際出願番号を \_\_\_\_\_ とし、  
（該当する場合） \_\_\_\_\_ に訂正されました。

N was filed on November 22, 2000 as **United States Application Number** or **PCT International Application Number** PCT/JP00/08233 and was amended on \_\_\_\_\_ (if applicable)

私は、特許請求範囲を含む上記訂正後の明細書を検討し、内容を理解していることをここに表明します。

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

私は、連邦規則法典第37編第1条56項に定義されたとおり、特許資格の有無について重要な情報を開示する義務があることを認めます。

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

私は、米国法典第35編119条(a)-(d)項又は365条(b)項に基づき下記の、米国以外の国の少なくとも一カ国を指定している特許協力条約365(a)項に基づき国際出願、又は外国での特許出願もしくは発明者証の出願についての外国優先権をここに主張するとともに、優先権を主張している、本出願の前に出願された特許または発明者証の外国出願を以下に、枠内をマークすることで、示しています。

I hereby claim foreign priority under Title 35, United States Code, Section 119(a)-(d) or 365(b) of any foreign application(s) for patent or Inventor's certificate or 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or Inventor's certificate or PCT International application having a filing date before that of the application on which priority is claimed:

## Prior Foreign Application(s)

外国での先行出願  
P11-330805 Japan November 22, 1999

(Number) (番号)	(Country) (国名)	(Day Month Year Filed) (出願年月日)
P2000-251996	Japan	August 23, 2000

(Number) (番号)	(Country) (国名)	(Day Month Year Filed) (出願年月日)
------------------	-------------------	-----------------------------------

私は、第35編米国法典119条(e)項に基づいて下記の米国外特許出願規定に記載された権利をここに主張いたします。

(Application No.) [出願番号]	(Filing Date) [出願日]
-----------------------------	------------------------

私は、下記の米国法典第35編120条に基づいて下記の米国外特許出願に記載された権利、又は米国を指定している特許協力条約365条(c)に基づき権利をここに主張します。また、本出願の各請求範囲の内容が米国法典第35編112条第1項又は特許協力条約で規定された方法で先行する米国外特許出願に開示されていない限り、その先行米国外出願書提出日以降で本出願書の日本国内または特許協力条約国際提出日までの期間中に入手された、連邦規則法典第37編1条56項で定義された特許資格の有無に関する重要な情報について開示義務があることを認識しています。

## Priority Not Claimed

優先権主張なし

(Number)	(Country)	(Day Month Year Filed)
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(Number)	(Country)	(Day Month Year Filed)
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I hereby claim the benefit under Title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below.

(Application No.) [出願番号]	(Filing Date) [出願日]
-----------------------------	------------------------

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s) or 365(c) of an PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application.

**Japanese Language Declaration**  
(日本語宣言書)

(Application No.)  
(出願番号)

(Filing Date)  
(出願日)

(Status: patented, pending, abandoned)  
(現況: 特許許可済, 係属中, 放棄済)

Application No.)  
(出願番号)

(Filing Date)  
(出願日)

(Status: patented, pending, abandoned)  
(現況: 特許許可済, 係属中, 放棄済)

私は、私自身の知識に基づいて本宣言書中で私が行なう表明が真実であり、かつ私の入手した情報と私の信じることに基づく表明が全て真実であると信じていること、さらに故意になされた虚偽の表明及びそれと同等の行為は米国法典第18編第1001条に基づき、罰金または拘禁、もしくはその両方により処罰されること、そしてそのような故意による虚偽の声明を行なえば、出願した、又は既に許可された特許の有効性が失われることを認識し、よってここに上記のごとく宣誓を致します。

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

委任状: 私は下記の発明者として、本出願に関する一切の手続きを米特許商標局に対して遂行する弁理士または代理人として、下記の者を指名いたします。(弁理士、または代理人の氏名及び登録番号を明記のこと)

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (list name and registration number)

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Japanese Language Declaration  
(日本語宣言書)

S00 P1350 U\$00

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